PB-234 499

WET SYSTEMS FOR RESIDENTIAL REFUSE COLLECTION

A CASE STUDY FOR SPRINGFIELD, MASSACHUSETTS

CURRAN ASSOCIATES, INCORPORATED

PREPARED FOR

ENVIRONMENTAL PROTECTION AGENCY

JULY 1974

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TECHNICAL REPORT DATA

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1. REPORT NO.
EPA-670/2-74-038

2.

3.
PB 234 499

4. TITLE AND SUBTITLE
WET SYSTEMS FOR RESIDENTIAL REFUSE COLLECTION:
A CASE STUDY FOR SPRINGFIELD, MASSACHUSETTS

5. REPORT DATE
July 1974; Issuing Date

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
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8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Curran Associates, Inc.
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10. PROGRAM ELEMENT NO.
1DB064/ROAP-09ADA/Task 04

11. CONTRACT/GRANT NO.
68-03-0183

12. SPONSORING AGENCY NAME AND ADDRESS
National Environmental Research Center
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

13. TYPE OF REPORT AND PERIOD COVERED
Final Report

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES
See also EPA-670/2-74-037, EPA-670/2-74-065, EPA-670/2-74-066, and EPA-670/2-74-068 (-068 is the Summary, not yet published)

16. ABSTRACT

This is the third in a series of technical reports evaluating the economic and technical feasibility of wet systems for residential refuse collection. The major focus of this report is a documentation of a case study implementation of the wet systems concept in the Springfield, Massachusetts, urbanized area. Included are detailed analyses of the problems of hydraulic transport of ground refuse in the Springfield sewer system, treatment of a modified wastewater treatment plant; the impact on resource recovery and conventional solid waste management; socioeconomic, institutional and fiscal ramifications; and a total systems cost analysis that shows annual per household costs for refuse and sewage management to rise from $39 to $110-$140 under a wet systems implementation. However, an analysis of the refuse grinder in terms of a domestic appliance bought for convenience reasons indicates that if initial cost could be kept below $300, such grinders would gain consumer acceptance. If on this premise the cost of grinding is excluded from the cost comparison to the public sector, costs might under certain circumstances justify implementation falling possibly to $35-$40 per household per year. Nevertheless, implementation is judged to be at least a decade distant due to still unresolved technical uncertainties and a program of further laboratory investigations is recommended even prior to a demonstration scale study.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
*Refuse, Collection, Sanitary sewers, Garbage disposal, Economic analysis, *Pipeline transportation, Mathematical models, Sewage treatment, *Grinders	*Solid waste collection, Ground refuse transport, *Home refuse grinders, Economic feasibility study, *Hydraulic transport, *Combined refuse/sewage treatment	13B

18. DISTRIBUTION STATEMENT
RELEASE TO PUBLIC

19. SECURITY CLASS (This Report)
UNCLASSIFIED

20. SECURITY CLASS (This page)
UNCLASSIFIED

21. NO. OF PAGES
220

22. PRICE
5.75

EPA Form 2220-1 (9-73)

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EPA-670/2-74-038
July 1974

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REVIEW NOTICE

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

As part of these activities, the study described here presents an investigation to determine the feasibility of hydraulic transport of ground refuse in sanitary sewers of conventional design.

This report is one of several final reports examining the technical and economic feasibility of collecting and transporting residential solid wastes via an underground, wet pipeline (sewer) system. The research was aimed at improving the overall management and reuse of solid waste to the benefit of both the individual citizen and the national environmental picture. All possible aspects of this new concept were considered including the physical, mechanical, chemical, and socio-economic, and the environmental. It is the conclusion of the study that the wet system concept is extremely feasible technically, socially, and environmentally; but that the system's economics do not appear too reasonable at this time except for specialized applications.

A. W. Breidenbach, Ph.D.
Director
National Environmental
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ACKNOWLEDGMENTS

This study was conducted by Curran Associates, Inc., Engineers and Planners, Northampton, Massachusetts, under the direction of Dr. Peter M. Meier. Mr. Donald Cooper served as project engineer and contributed to the analysis of Environmental Impact and Refuse Collection practices. Mr. Jochen Kuhner and Dr. Roger Bolton conducted the analyses of solid waste management practice and socioeconomic impact, respectively; hydraulic transport and treatment were investigated by Mr. James Martel and Mr. Michael Joyce. The chapter on grinding costs was prepared by Mr. Thomas Sanders, consultant to Curran Associates.

The writers gratefully acknowledge the assistance of Mr. Wylie C. Hubbard, Superintendent of the Department of Public Works, city of Springfield, Massachusetts, and his staff, without whose cooperation this study could not have been satisfactorily conducted. In particular, we acknowledge the contribution of Mr. Lawrence J. Dowd, Deputy Superintendent of the Division of Solid Wastes, who provided major assistance in the collection of data and information. Others whose assistance we acknowledge include Mr. Paul Sullivan, Chief Foreman, and Mr. Donald Ferris, Foreman, both of the Division of Solid Waste, Springfield; in the Springfield Sewer Division, Mr. James Moyland, Deputy Superintendent, Mr. John Risinski, Chief Sewage Treatment Plant Operator, and Mr. Fred Mascola, Working Foreman; in the Engineering Division, Mr. Joseph Cote, Office Engineer, and Mr. Tony Masuch, Engineer; Mr. George E. Sweeney, Manager of the Springfield Water Department; Mr. John Godfrey, Civil Engineer in the Springfield Department of Public Works; Mr. Edward Beaudry in the personnel office of the city of Springfield; Mr. James Fitchet, Chief Accountant of the Department of Public Works, Springfield. Finally, Mr. David Goodman of Harry Goodman, Inc., Springfield Massachusetts, provided valuable information on recycling.

The writers also benefited greatly from the comments and suggestions of the EPA Project Officers, Mr. Donald Oberacker and Dr. Harry Bostian. The report reviews by Mr. O. Albrecht, also of the EPA National Environmental Research Center in Cincinnati, were similarly appreciated.

The responsibility for the accuracy and opinions expressed in this report, however, remains solely that of the writers.

SUMMARY OF CONCLUSIONS

The major conclusions of this case study can be summarized as follows:

1. Implementation of a wet system for residential refuse collection in the case study area of Springfield, Massachusetts, or any other urban area in the United States, is at least a decade distant.
2. The ability of a gravity sewer system to successfully transport the glass and ceramics fraction of refuse remains questionable, and ferrous metals must definitely be excluded. Maximum sewer flow velocities encountered in many parts of the Springfield system are below necessary scour velocities as determined by Foster-Miller. The frequency of collection of nongrindables is likely to be higher than might be expected because of seasonal variations and the substantial quantities of bulky wastes not amenable to grinding. The adequacy of available grinding water without substantial additions of fresh water is also questionable.
3. To the extent that realistic cost estimates can be made in the face of the technical uncertainties that still exist, total per household expenditures on waste management would double under a wet systems implementation, rising from \$39 per year to \$110 - \$140 per year. However, if the cost of the grinder is excluded, costs to the public sector under the wet system might decrease to as low as \$34 - \$38 per year.
4. Given the premise of technical feasibility, any implementation that does occur is likely to be gradual, not unlike the spread of garbage grinders and trash compactors, and will depend on the development of a domestic grinder at a cost consistent with consumer acceptance and its perceived domestic convenience benefits. Existing grinding concepts are not regarded as practically feasible.
5. Analysis of the socioeconomic impacts of a wet system implementation shows the resultant reduction of the refuse collection labor force in Springfield to be a minor problem, due to other employment opportunities within the public works sector and because of the gradual nature of system implementation.
6. The presence of numerous combined sewers in the Springfield area is a serious barrier to the wet systems concept. This problem apart, our investigations show that an appropriately modified treatment facility can produce effluents of comparable quality to conventional effluents at plants treating only sewage.

SUMMARY OF RECOMMENDATIONS

The presently available factual evidence is still insufficient to make definitive judgments on the technical feasibility of the wet systems concept. This study has therefore identified and recommended a sequence of bench-scale investigations designed to resolve these uncertainties. Successful completion of the following studies, presented in order of priority, are regarded as prerequisites to further investments at a demonstration scale:

1. Study of hydraulic transport of ground refuse under unsteady flow and load conditions representative of sewer laterals in residential areas.
2. A field survey of refuse generation, water consumption and sewage generation to establish the daily correlation of refuse and sewage generation for individual households, a necessary prerequisite for the development of realistic grinder design specifications.
3. Evaluation of the wet systems concept from an energy consumption viewpoint.
4. Evaluation of potentially hazardous and nontreatable components in ground refuse - sewage mixtures, using advanced instrumentation methods on simulated treatment plant streams.
5. Development of alternative grinding concepts, including a laboratory study of the mixing characteristic of refuse slurries and domestic sewage and actual construction and testing of a prototype grinder. The inability to develop a grinder within the cost limits established in the present study and the specifications to be developed under task 2 would be sufficient to abandon the concept as economically or technically unrealistic.
6. Re-evaluation of the economic and overall technical feasibility of the concept using the new information available from the above studies.

CHAPTER I

INTRODUCTION

This report is the third of four reports prepared by Curran Associates under a contract from the EPA Solid Waste Research Laboratory to study the technical and economic feasibility of Wet Systems for Residential Refuse Collection.[1] A first report undertook a preliminary assessment of economic and technical feasibility with a veiw to establishing the order of magnitude of costs involved and to identify the major areas of technical uncertainty.[2] A second report analyzed the economics of processing and disposal of refuse sludges, published separately in view of its possible interest to an audience not necessarily also interested in the wet systems concept.[3] A reading of at least the first of these two reports is, however, recommended prior to embarking on the material presented in this study, as the necessary background will not be repeated.

In this report we attempt a detailed evaluation of the wet systems concept using a case study area to develop specific conclusions and cost estimates for the conditions encountered in an area typical of the Nation's urbanized regions. And finally, a fourth report documents the computer program developed for the assessment of treatment costs.[4] Again, the motivation for a separate report is the possible interest of the subject matter to an audience not necessarily interested in wet systems for refuse collection.

Objectives of the Case Study

The case study phase of the overall evaluation of the wet systems concept has the following major objectives:

- To develop specific conclusions on the technical and economic feasibility of the concept on the basis of the conditions actually encountered in the case study area, and to extrapolate findings to other urban areas.
- To identify the cost ranges for individual system components such that the overall system be competitive with other existing or potential solid waste management concepts.
- To consider in as much detail as presently possible the socioeconomic impact of a wet systems implementation.
- To evaluate the environmental impact of the wet systems concept.
- To define the critical areas of research necessary to resolve remaining technical, environmental and economic uncertainties.

Selection of the Study Area

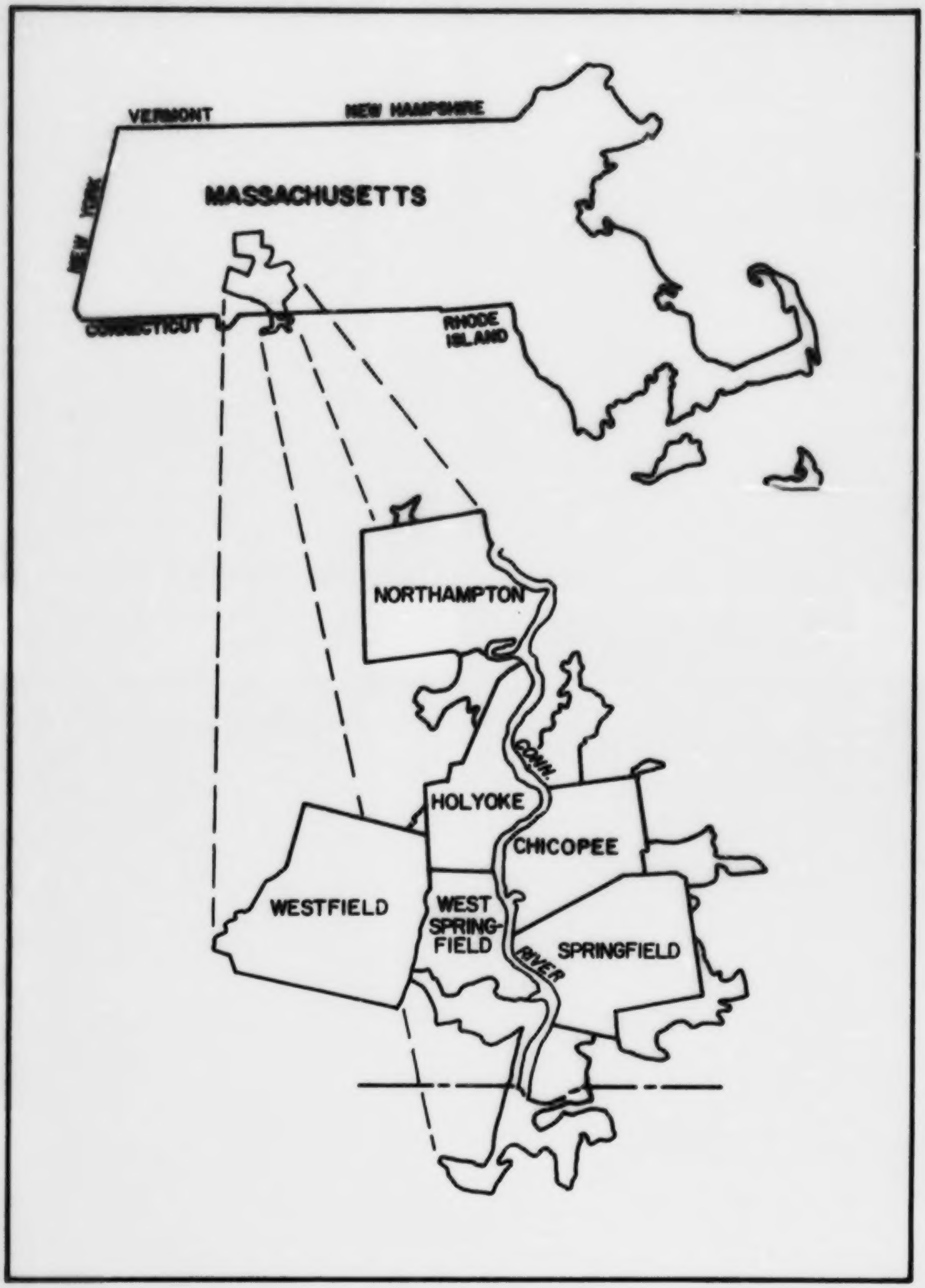
The choice of Springfield urbanized area as the case study, and the city of Springfield as its major focus, was not dictated solely by its proximity to the contractor's home office and its representative size. Located in the picturesque Connecticut River Valley in western New England, considerable environmental awareness exists among its inhabitants, evidenced for example by its relatively advanced refuse recycling efforts. The area has recently completed a planning program for both solid waste disposal and wastewater treatment and its wastewater treatment plant is in the process of being upgraded from primary to secondary treatment. Thus the case study addresses an area that is in a very active stage of environmental improvement, and hence displays an interest in the evaluation of innovative concepts. Indeed, the willingness of the city officials to assist the contractor in his investigations, especially the superintendent of the city's Department of Public Works and his deputies in charge of the refuse and sewer divisions, has been of valuable assistance. Moreover, Springfield exhibits many of the problems that must be addressed in a realistic evaluation of the concept, including the presence of a significant proportion of combined sewers and significant seasonal variations.

In retrospect, perhaps the major apparent disadvantage of the choice of Springfield as a case study area is the fact that the wet system implementation has had to be compared to an existing solid waste collection system of high cost-efficiency. But we have thereby avoided the pitfall of overestimating the benefits of a wet system implementation by comparison to an existing collection system that could easily be improved by other means. We recognize, of course, that there are undoubtedly areas of the country where many of the problems of a wet system encountered in Springfield do not exist or are of a much lesser magnitude. But the most important consideration has been to ensure that all important factors be addressed so that the research priorities that this study seeks to define have in fact been based on a complete evaluation of possible conditions.

Finally, it should be stressed that we are not in any way making recommendations for changes to Springfield's existing practices or presently planned improvements. All of the plans and recommended courses of action presented herein are only for the purposes of the case study and presuppose a hypothetical implementation of the wet systems concept. Indeed, the conclusions of the study show that feasibility of the concept is many years distant, be it Springfield or any other urban area.

An Introduction to Springfield, Massachusetts

Springfield is part of the Springfield-Chicopee-Holyoke Standard Metropolitan Statistical Area, located in the southwestern portion of Massachusetts, as shown on the map of Figure 1. The principal geographic feature of the area is the Connecticut River, one of New England's major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NORTHAMPTON
CONN.
HOLYOKE
CHICOPEE
WESTFIELD
WEST SPRING-FIELD
SPRINGFIELD
RIVER

Figure 1: Location of study area

waterways. The SMSA is somewhat cross-shaped extending about 24 miles (38.6 km) in both east-west and north-south directions, encompassing over 310 square miles (803 sq km). The southernmost portion of the SMSA crosses the Massachusetts state line into Connecticut. Almost the entire area lies in the Connecticut River Valley, and is drained by the Connecticut or one of its two major tributaries, the Chicopee River from the east and the Westfield River on the west.

The city of Springfield, situated in Hampden County, is the demographic and industrial center of this area. With respect to its housing types and neighborhoods, Springfield shows remarkable diversity for a city of its size. The older central business district is the object of extensive urban renovation, making the downtown area a pleasant, busy center for business activities. In a belt surrounding the business district is a former suburban area from an earlier era in the city's history. The prevalent housing, large homes originally built 40 to 80 years ago, has now been converted into multi-family units. This belt contains some of the poorest neighborhoods in the city, the Puerto Rican area in the "North End" and the Black neighborhood to the east. Progressing radially out from the downtown area, beyond the older suburban area, is a sector of middle class neighborhoods which occupy a large portion of the city in a path running north-south. Even though population trends are to the contrary, there is considerable development activity in the city: nowhere is this more apparent than in the newer attractive suburban developments occurring in the southeastern sections of the city. Commercial development in the form of suburban shopping centers may also be seen in this quickly growing sector, providing consumer goods and services for residents of these outlying neighborhoods.

Industry in the past has clustered around the waterways which border the city; the Connecticut in the west and the Chicopee to the north. While these areas continue to be the home for many industries, new industrial growth is also occurring along the two interstate highways which intersect in Springfield; Route I-91 running north-south and I-291 cutting across the city in the north.

Population. The population of Springfield, after a period of continuous growth up to 1960, has recently experienced a slight decline, as shown in Table 1. This population decrease of 6.05 percent between 1960 and 1970 is typical of central cities throughout the nation and is in fact relatively slight compared to the 15 and 11 percent declines between 1955 and 1965 occurring in Massachusetts' two other large cities, Boston and Worcester, respectively.

The city's boundaries enclose an area of 31.7 square miles (82 sq km) making its average density in 1970 5,170 persons per square mile (2,000 persons/sq km).

A renewal of population growth in the future is foreseen by the Raytheon Service Company[5] in their recent report for the Massachusetts Department of Public Works. As shown in Table 2, a slow but steady increase amounting to a 4.02 percent population gain by the year 2000 is forecast. The same study also anticipates a much more dramatic increase in per capita solid waste generation.

Table 1: Past population trends

Year	Population
1920	129,614
1930	149,300
1940	149,554
1950	162,389
1960	174,463
1965	165,520
1970	163,905

Table 2: Population and waste production

Year	Population	Solid Waste (tons/yr)	Per Capita (lbs/day)
1970	163,905	90,023	3.00
1975	166,125	96,389	3.17
1980	168,430	107,500	3.49
1985	168,750	110,330	3.58
1990	169,200	118,101	3.82
2000	170,500	131,670	4.23

Socioeconomic Characteristics. Reflecting its varied nature, Springfield has a rich mixture of racial and ethnic groups. Over twelve percent of the population is Negro. Fully 32 percent of its citizens are of foreign stock, and 9 percent are foreign born. Major ethnic influences come from the large Spanish-speaking community, primarily Puerto Ricans; from persons of Italian descent; and from the Polish community.

Springfield has a labor force of 64,398 persons, or approximately 40 percent of the population, according to the 1970 U.S. Census. Wide variations in income can be observed over the city varying from the extreme poverty of the slum areas to the wealthy southeastern suburbs. The mean income of $10,358 per family for the city is below the mean income for U.S. urban areas of $12,777. Likewise, the city-wide median of $9,612 income per family is below that for all U.S. urban areas of $10,618, indicating an income distribution skewed toward the lower ranges.

Land Use and Zoning. A master plan for land use has been completed for the greater Springfield area. The results of a land use inventory conducted in 1965 are given in Table 3, from which it appears that Springfield does have land available for further growth. However, as land which is suitable for development becomes scarcer, high competition between residential, commercial and industrial interests, and conservationists can be expected. Recreation and open space land uses make up a relatively high portion of the total; perhaps a good indication of the scenic and relaxed urban atmosphere which exists in this city.

Table 3: Land use inventory (1965)

Type	Acres (x 0.405=ha)	Percentage of Total
Residential	6,860	32
Commercial & Industrial	1,926	9
Recreation & Open Space	2,664	13
Agriculture	18	1
Others[a]	4,932	23
Vacant Land[b]	4,781	22

[a] Includes transportation, public utilities, public building land uses as well as water bodies.

[b] Includes substantial amount of land areas with steep slopes (15 percent or greater) and wetlands.

Zoning in the city is a responsibility of the zoning office in the planning board. The planning board has a paid staff and exercises subdivision control powers. A zoning map and a copy of the zoning ordinance are available from the planning board office of the city. The city is also a member of the Lower Pioneer Valley Regional Planning Commission, which is the comprehensive advisory, planning, and reviewing agency for all communities within Hampden and Hampshire counties.

Industrial Development. Although Springfield has been experiencing decreasing population, it has remained the commercial and employment center of the lower Connecticut River Valley in Massachusetts. In 1971, 3,392 firms engaged in manufacturing and trade reported to the Massachusetts Division of Employment Security. These firms employed 60,204 persons and had an annual payroll of $432,377,576. In the manufacturing branch, the six most important groups in order of importance as employers were machinery, chemicals (mostly plastics), printing and publishing, accessories, apparel and other finished goods.

The city is actively engaged in promoting the movement of industry into Springfield through organizations such as the Industrial Development Finance Commission, and indications are that Springfield will experience continued growth in the industrial sector.[6] Industrial growth is expected to occur primarily along Interstate routes 291 and 91, with the bulk of industrial land in the northeastern outlying areas of the city. This industrial belt and other smaller planned industrial areas are evident in the land use plan for the Lower Pioneer Valley.[7] Presently, 9 percent of the land in Springfield is used for industrial and commercial purposes.

Transportation Networks. Springfield is located on one of the major transportation crossroads in the New England area. Interstate highways I-91 (north-south) and I-90 (the Massachusetts Turnpike, east-west) intersect just north of the city limits. According to the Urbanized Area Transportation Study,[8] the highway network is adequate and provides Springfield with rapid roadway connections both within the city and between other industrial centers.

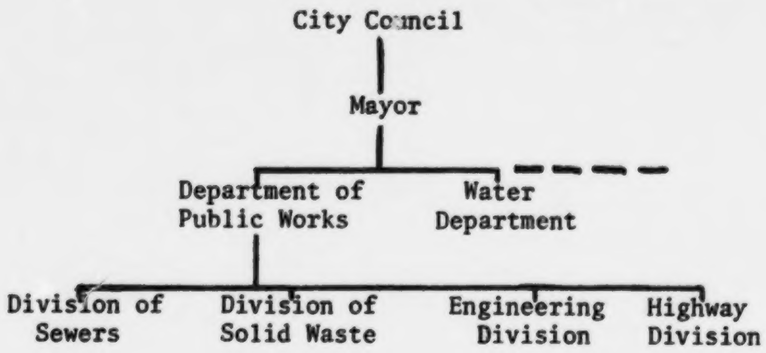
Springfield is served by two railway systems, the Boston and Maine providing service to the north, and the Penn Central offering service to the south, east, and west. Bradley International Airport, about 30 minutes distant on I-91 south of Springfield, links the city to both local and long-distance air transportation networks.

Government Organization. Presently, the structure of the city government is mayoral, with a city council. The major functions of the government are divided into departments controlled by superintendents. Within the departments, divisions are headed by deputy superintendents.

Of primary interest to our analysis is the organizational structure of the departments concerned with solid waste collection and disposal, sewerage, and water supply (see Table 4). The Division of Solid Waste has responsibility for street cleaning, snow plowing, and refuse collection. Ice control and snow removal are handled by the Highway Division. The Division of Sewers operates and maintains the sewers and related facilities and the sewage treatment plants at Indian Orchard and Bondi Island.

Selection of Detailed Study Neighborhoods. For the purpose of gaining detailed information on existing collection practices and refuse generation in the SMSA, four individual study neighborhoods were selected. At the level of detail proposed for these analyses, coverage of the entire SMSA was neither feasible nor necessary because it was felt that careful selection and study of representative neighborhoods would yield information relevant to the whole SMSA. Due to the scarcity of existing

Table 4: Structure of Springfield city government



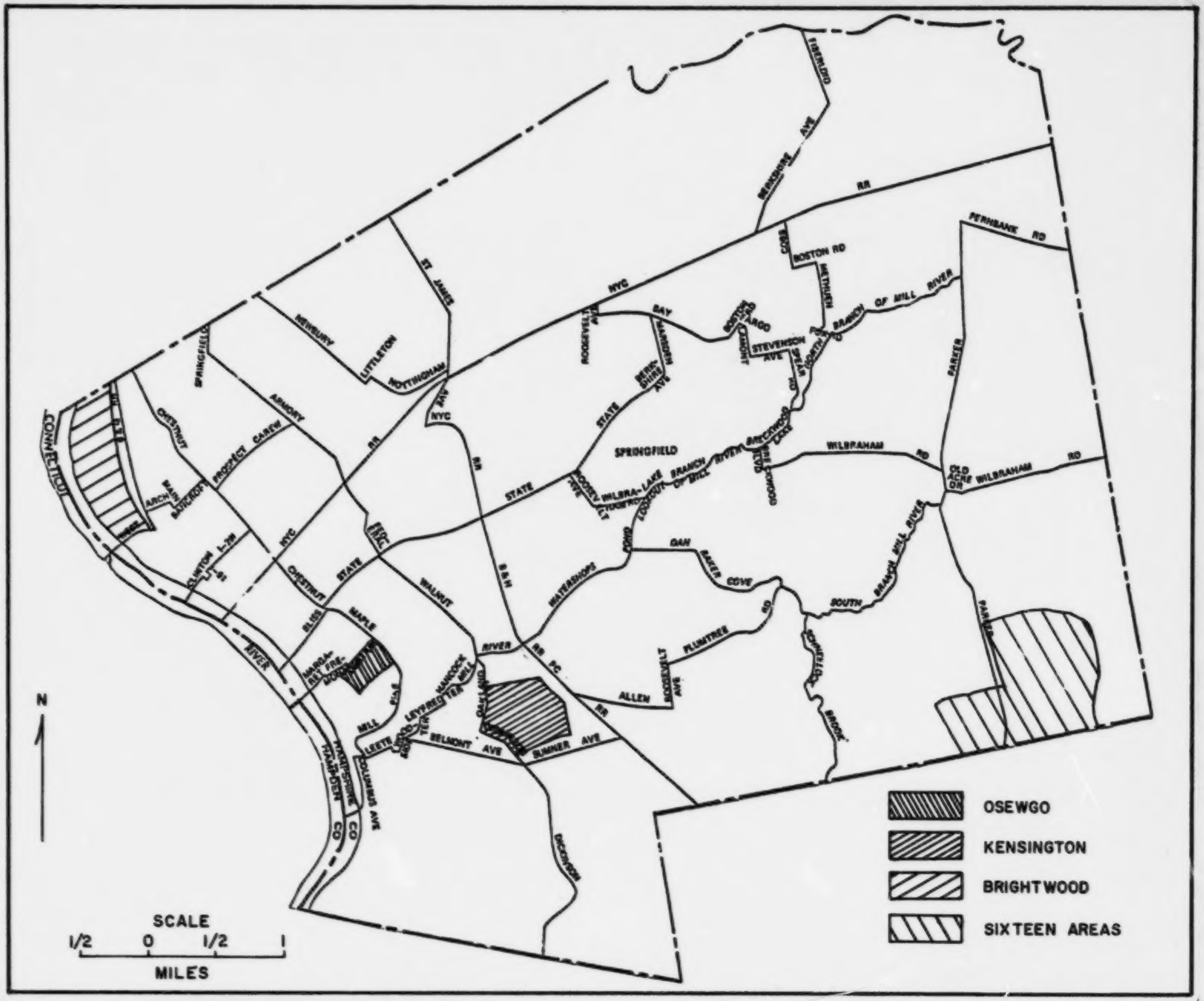
information at the neighborhood level, this new data would add substantially to our information base. Additionally, new data obtained for these neighborhoods could serve as a check for comparisons to data from other sources.

Selection of the study neighborhoods was based primarily on their household density and their socioeconomic stature in the community. Household density is related to the population density and the type of housing prevalent in the neighborhood. Socioeconomic status will be reflected in mean income, property values and to some extent in the percent of owner-occupied units. Superimposed on these was the consideration that the neighborhoods should correspond to the area covered by a daily collection route to facilitate our detailed studies of existing refuse collection practice.

A cross section was desired to represent each envisioned type of grinder installation: 1) individual home; 2) single grinder per structure; and 3) block or neighborhood grinder. As discussed in an earlier work[9] these alternatives correspond to neighborhoods with primarily single family detached homes, multi-family housing and apartment structures, and neighborhoods of high residential density, respectively.

Socioeconomic parameters as reflected by income and property value were suspected to influence quantity and type of refuse generated. Following is a brief geographic and neighborhood description of the representative areas, with their locations in the city shown on Figure 2.

1. Brightwood. This is in the extreme northwest corner of Springfield, comprising most of census tract 8007. It is bordered by Lowell, Riverside, Moore and Plainfield Streets including Knowlton, Ormsbee and the portions of Abbee and Bowland Streets east of Plainfield. The Brightwood neighborhood is the object of extensive redevelopment imporvement projects. It includes older single family detached and newly built low income low-rise and high-rise apartments, including a high proportion of duplex housing. Census tract information shows this to be a lower-middle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WILBRAHAM RD
PARKER
BOSTON RD
SOUTH BRANCH MILL RIVER
WALNUT
CHESTNUT
MAPLE
ALLEN
SUMNER AVE
BELMONT AVE
DICKINSON
COLUMBUS AVE
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ARMORY
WATERSHOPS

Figure 2: Detailed study neighborhoods in Springfield, Massachusetts

class area, probably consisting of a mix of the middle class area in the north and the lower income development and poverty area in the south. The mean income of $7,122 and median property value of $10,000 are both well below city-wide averages. The average number of households per structure is 2.87, indicating perhaps that single family or building type grinders are applicable. The number of persons per household is the highest in the city, indicating large families. Large numbers of householders in this community rent their dwelling. Typical housing types are shown on Figures 3, 4, and 5.

2. Oswego Area. This is an apartment community located in the southern extreme of the downtown business district. It is located in census tract 8020 and is bounded by Main, Adams, Richelieu and Oswego Streets, including Central Street Alley and Ashmun Street. The predominant type of housing is four-story apartment buildings thirty to forty years old with 8-10 units per structure. Included also is some dilapidated housing along Central Street and a few run-down single family homes. This area was chosen because the tight grouping of apartments might make it amenable to a neighborhood grinder. There are 4.18 households per structure over the entire tract, with a much higher figure of 8-10 if only the apartment area is considered. Income is below average, property value is roughly average for the tract area as a whole; in the apartment district, income may be higher. The persons per household data indicates small families or couples comprise the typical family unit in this section. Over 35 percent of the units are rented. The area is influenced by the commercial downtown area only 2 blocks to the west. Typical housing is shown in Figure 6.

3. Kensington Area. This is an older residential area in the southern central portion of the city. Bordered by, but not including, Dickenson, Oakland, Orange, White, Scott and Alderman Streets, the neighborhood consists almost exclusively of duplex housing units 30-50 years old. The average number of households per structure for all of census tract 8023 is 2.08. A solidly middle class neighborhood, the income and property values are both at the city-wide average. Family size is averaged at 3.02 persons per household. About 60 percent of the households rent their living quarters. This area might be ideal for grinder installation on a per structure basis. Typical housing is shown on Figures 7 and 8.

4. Sixteen Acres. Located in the extreme southeast corner of the city in census tract 8016.04, this is part of the Sixteen Acres community. It is a typical suburban area, containing only single family detached homes, and hence the number of households per structure is 1.0. Income and property value figures show it to be one of the wealthiest sections of the city. It is bordered by and includes Fair Oak and Parker Streets and the city limits to the east and south. Additionally, included are Allen Street between Cooley and Parker, Briarcliff Road, Ellendale Circle, Lindsay Road and Paulk Terrace. Virtually all houses are owner-occupied; family size is high (3.63), indicating a young neighborhood with families having children at home. Typical housing is shown on Figures 9 and 10.

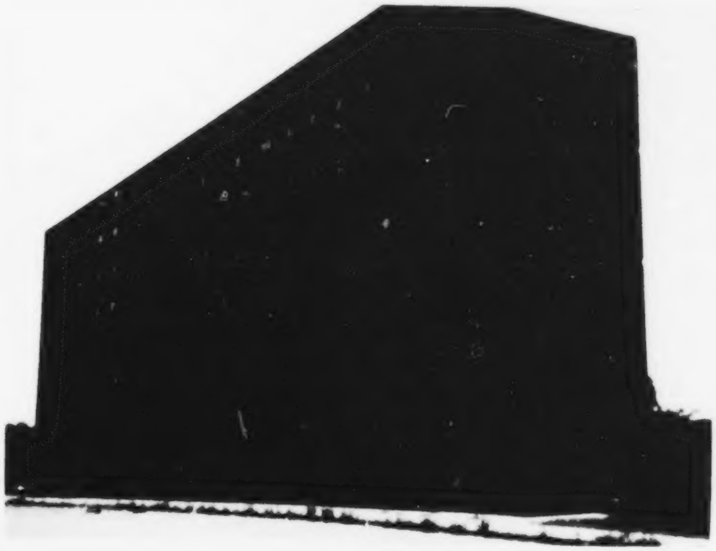

Figure 3: Low income housing project in Brightwood

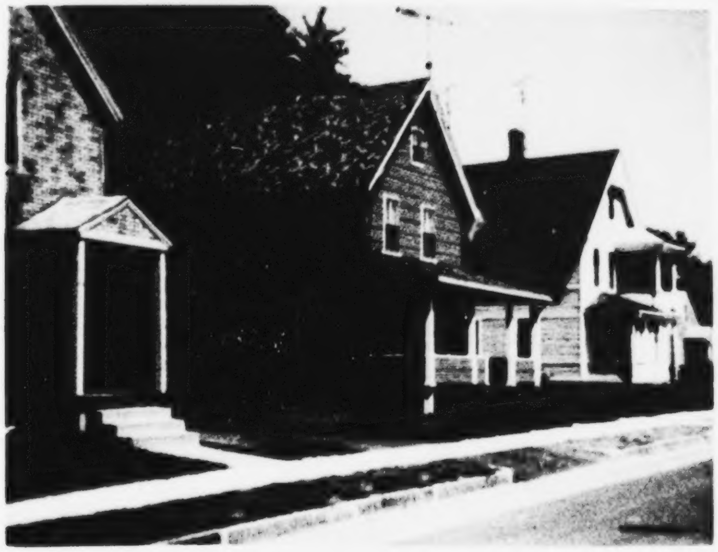

Figure 4: Older community housing in Brightwood

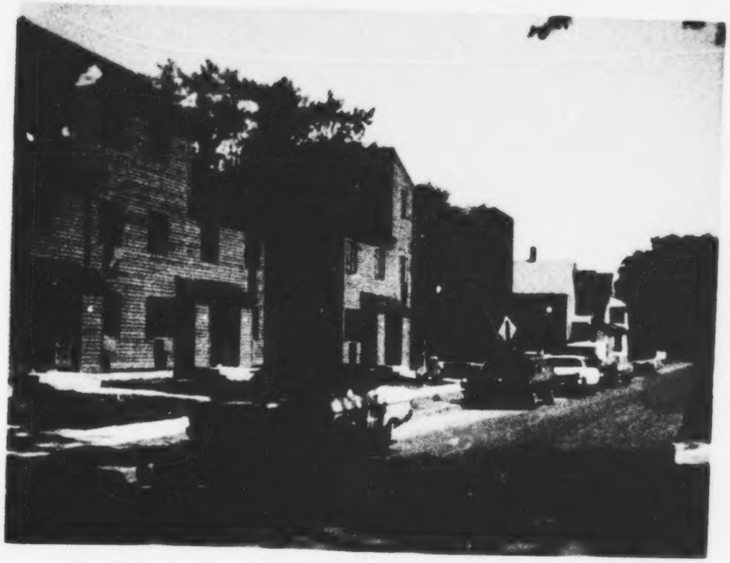

Figure 5: Redevelopment project at Brightwood

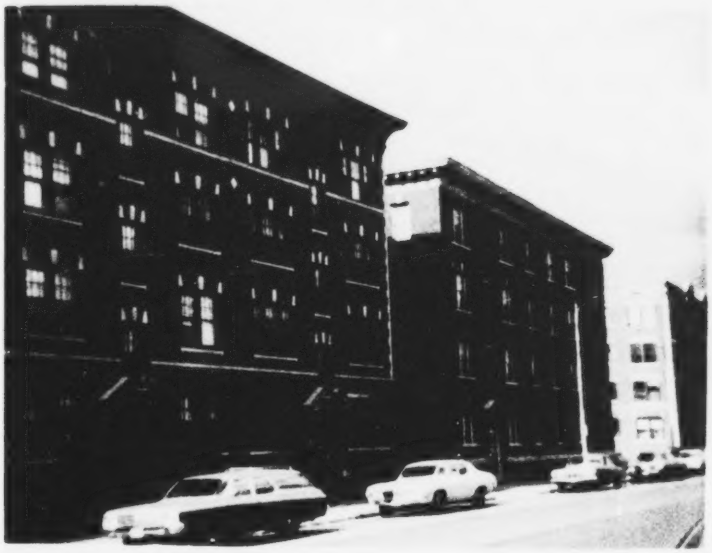

Figure 6: Multi-unit structures in the Oswego area

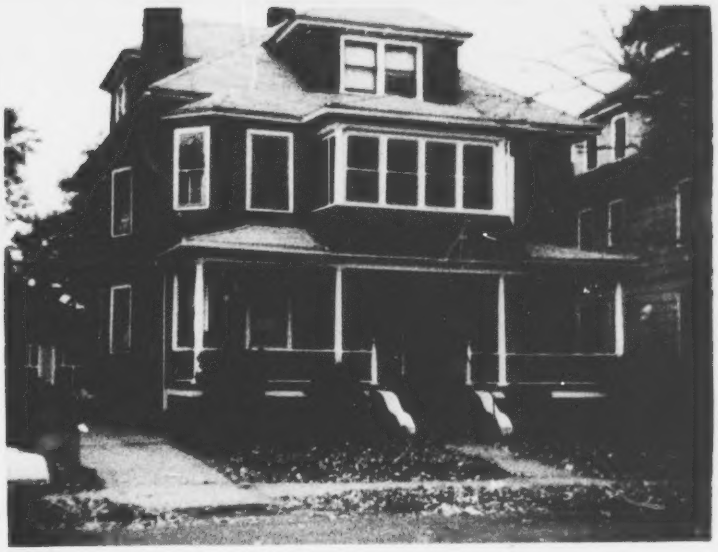

Figure 7: Kensington area

Figure 8: Multi-family homes in the Kensington area

Figure 9: Sixteen Acres

Figure 10: Sixteen Acres

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CHAPTER II

GRINDING

Introduction

The economic analysis of the preliminary assessment undertaken in Phase I of this study showed grinding to be the single most expensive component of a wet systems implementation. It was recognized, however, that in the absence of a refuse grinder actually having been built and tested, estimates of capital, installation and maintenance costs were subject to considerable uncertainty. The objective of the discussion presented in this chapter is to refine and update the cost estimates developed by Foster-Miller several years ago,[1] especially with a view to projecting the future costs of such an appliance. Foster-Miller's estimates were based on a determination of probable design, fabrication, material and production costs, and the cost of installation was based on engineering judgment. A subjective extrapolation of cost for a production level of 20,000 units per year was subsequently made, and these costs were used in the analysis of Phase I of this study.[2]

It can be argued that indications of the possible cost trend of a refuse grinder might be extrapolated from the study of cost trends of similar household appliances; similar to a refuse grinder in either use, such as the garbage grinder; in consumer appeal, such as the refuse compactor; or in similarity to electromechanical sophistication and probable industrial production technique such as the automatic dishwasher. Unlike the washing machine, all three appliances still have connotations of convenience rather than necessity, and, also unlike washing machines, are many years from market saturation. However, the Phase I analysis of grinding costs also showed that installation costs, and in particular the costs of replumbing necessary under the wastewater reuse concept, could exceed by a substantial margin the initial cost of the grinder itself. Consequently, the assistance of an experienced plumbing contractor was enlisted in an attempt to confirm and update the Foster-Miller estimates.

Several other aspects of the grinding step are discussed elsewhere in this report. The question of the adequacy of grinding water is closely related to hydraulic transport, and is addressed with specific reference to the Springfield Case Study Area in Chapter IV. The convenience aspects are analyzed from a socioeconomic viewpoint in Chapter VII, and the question of which refuse categories can be allowed for grinding is discussed in Chapter III.

Cost Trends of Comparable Appliances

The garbage grinder is clearly the appliance most similar to the refuse grinder in use and design, and its cost has fluctuated considerably in the past 25 years. In 1951, the average cost was $170.00 per year;[3] by 1953 the average cost decreased to $100.00, and by 1958, the cost ranged from $49.95 to $100.00 for the deluxe model.[4] Although the cost of the garbage grinder did not decrease in the time period from 1968 to 1973, the wholesale price of a low cost model increased only $5.00--from $24.00 to $29.00--and the cost of a more expensive model increased from $85.00 to $94.00.[5] Improved design, economies of scale, and competition, especially in the lost cost garbage grinders, have tended to decrease actual costs during the initial marketing periods of the 50's. And over the last 5 years, the costs of both a low cost and deluxe model have increased approximately 10 percent. However, the real costs of the garbage grinders to the individual, taking into account the rate of inflation, has unquestionably decreased. One yardstick of real cost that appeared appropriate is the consumer price index; if the cost of an appliance in year x is denoted C_x, and the consumer price index for that year denoted CPI_x, then the inflation adjusted cost of the product in year y is given by the expression:

$$C_y = CPI_y \frac{C_x}{CPI_x}$$

Using this expression for the period 1968 through 1973, inflation should have increased the cost of the deluxe grinder by $21.00. Yet the experienced cost increase was only $9.00, and we infer a decrease of $12.00 in real cost. Similarly, the real cost of the cheaper model decreased approximatley $1.00 during the same period of time. The recent development of the consumer price index is shown on Figure 11.[6]

Although the automatic dishwasher is not comparable to the refuse grinder in actual design or utility, it does approximate the size, weight and design complexity of a household grinder to such an extent that the cost of industrial fabrication, distribution and promotion of an automatic dishwasher may be an indication of the cost of a refuse grinder.[7]

In 1952, the automatic dishwasher rated best by Consumer Reports cost $354.95.[8] Seventeen years later a similar machine rated best cost $279.95[9]-- a net decrease of $75.00 and a $210.00 decrease in real cost to the consumer. During the latter part of the same period of time, more specifically 1961-1966, the average cost of the automatic dishwasher decreased from $236.00 to $180.00.[10] From 1968 to 1973, the wholesale costs of a low cost and deluxe model dishwasher increased from $123.00 to $141.00 for the former and $234.00 to $271.00 for the latter.

Again, the cost of the automatic dishwasher decreased during the initial periods of market development and design improvement. During the last 5 years, the price has increased somewhat, but at a much slower rate than expected. In fact, the real cost to the consumer of both the low cost and deluxe model has decreased within the last 5-year period by $12.00 and $20.00, respectively.

The domestic refuse compactor is of particular interest to our analysis as its only apparent benefit is domestic convenience. Indeed, the compactor does nothing more than reduce the volume of refuse, and has been

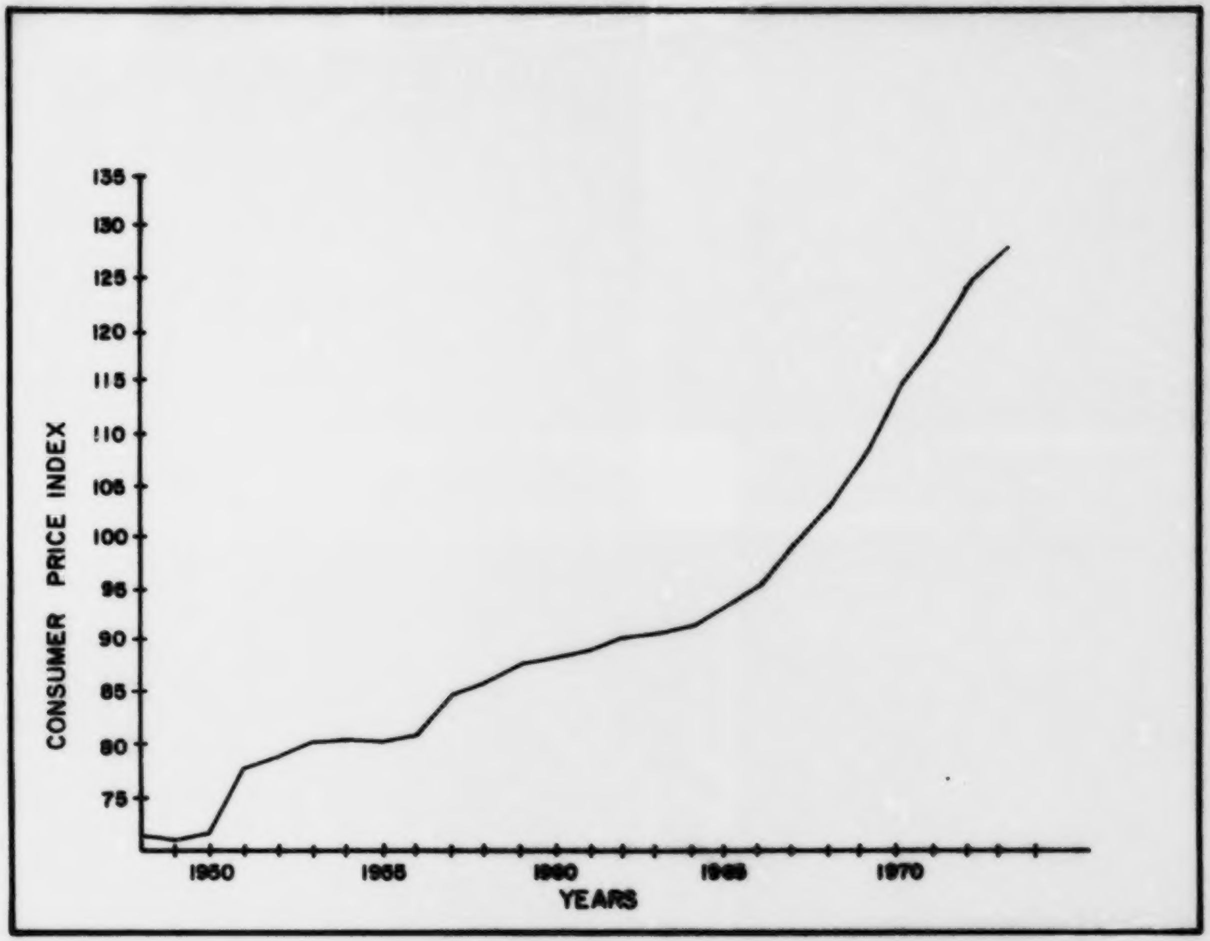

Figure 11: Consumer price index

described by one appliance executive as turning "...20 lbs. of trash into 20 lbs. of trash."[11] The scepticism sometimes expressed, however, does little to diminish the fact that sales of the appliance have been good, and that the market has recently attracted four new manufacturers.

The refuse compactor marketed by Whirlpool and Sears sold in 1971 at costs in the range of $200-$240.[12] Yet a recent announcement by Sears in September of 1973 indicated that the selling price of their refuse compactor would fall to $149.00,[13] a $51.00 decrease over a three year period.

The Appliance Industry Viewpoint

In view of the aforementioned similarities between the refuse grinder, the trash compactor and other similar appliances, a discussion of the appliance industry viewpoint on compactor sales is clearly pertinent to an assessment of the prospects of a refuse grinder. Unfortunately, attempts at enlisting the cooperation of the appliance industry did not yield much of value, forcing us to rely primarily on such published material as in fact available.[14]

The appliance industry sees trash compactors as an item having strong growth potential in the upcoming years. The trash compactor is the first new major domestic appliance in years, having been introduced only in 1970, and is therefore felt to have "novelty value." Somewhat optimistcally, compactor sales are hoped to parallel the dishwasher sales curve, shown in Figure 12. In reply to critics of the trash compactors' comparatively low sales volume, it is often pointed out that it took dishwashers many years, literally decades, to become the strong selling item they presently are.

The existing price level of around $200 is felt to be a strong selling point. This is considered low, and the prospects for even lower prices, as previously documented, are good. It is also noted that despite hindered consumer appeal of dishwashers at the time, some 15 years ago, that their price was in excess of $300, sales did ultimately accelerate as price decreases became possible. Indeed, one can identify a psychological barrier at a retail sales price of around $300, and any major appliance selling for less is considered likely to gain broad consumer appeal.

In view of the presently identifiable market for trash compactors, namely residents of relatively high-income, suburban single family home areas, speciality advertising that has maximum impact on sales is regarded as very effective. Retailers are pressing the manufacturers for additional advertising in this direction. And yet another perceived advantage is the feeling that because ecology and the environment will become of increasing concern to the householder, advertising can make the compactor appear to have a strong positive affect on the environment - thus appealing to the "environmentally conscious" consumer.

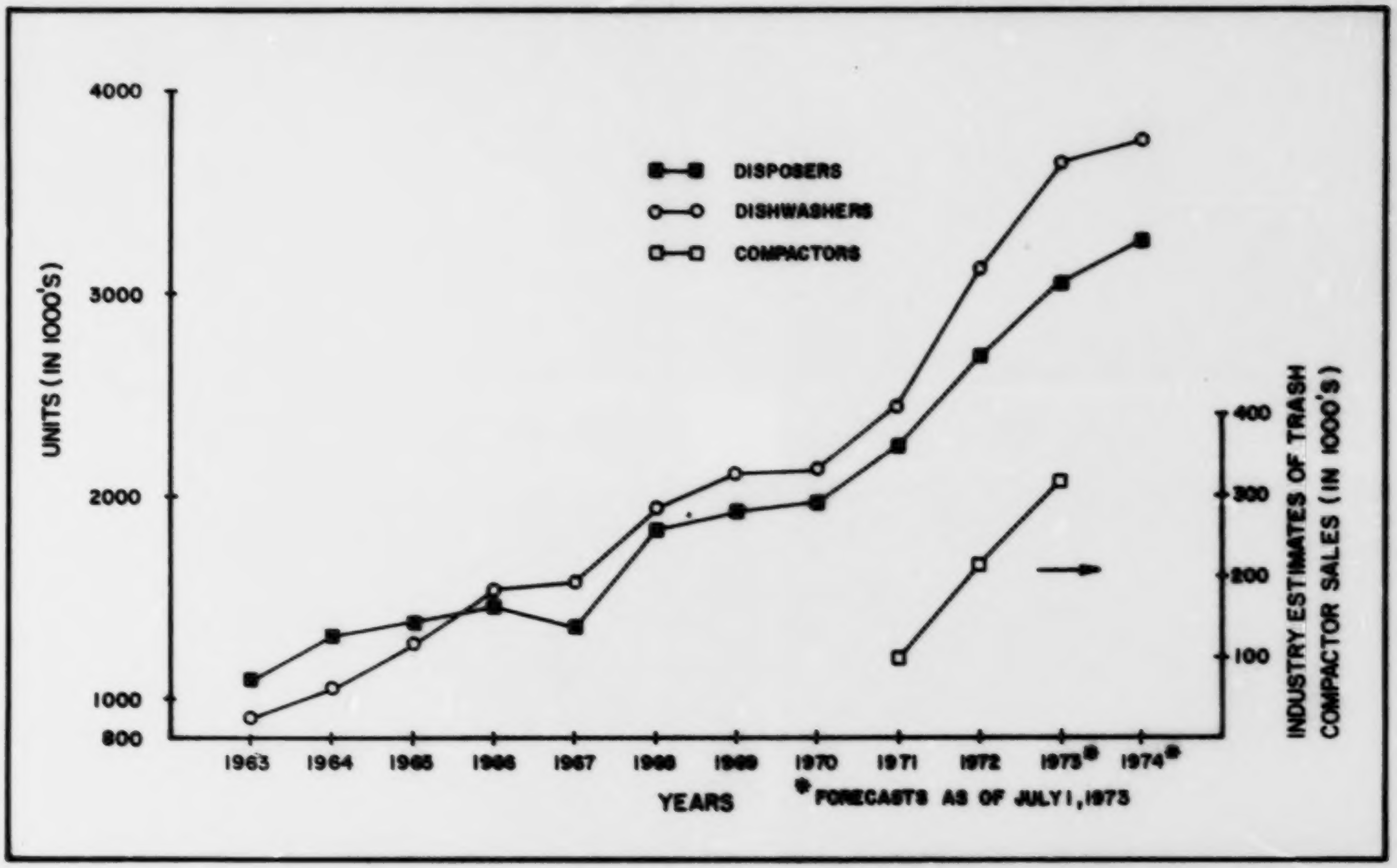

Figure 12: Factory shipments of selected domestic appliances

Implications for the Refuse Grinder

Whatever the shortcomings of the industry viewpoint toward trash compactors, and especially with regard to its exaggerated environmental benefits, it must nevertheless be concluded that some degree of consumer acceptance already exists, and that this is likely to grow.

Unquestionably, a refuse grinder would offer much greater convenience benefits than the compactor. Since refuse would be ground daily, there would not be the odor problem that characterises compactors. The special bags that are required for the compactors would no longer need to be purchased, nor would the compacted refuse need to be carried to the point of pickup, a task, incidentally, that because of the high density of the compacted product, would certainly be beyond the many persons unable to carry heavy loads.

There would of course be some relative disadvantages over the compactor, including that of higher noise levels and the need to periodically remove nongrindables. Nevertheless, it does not appear unreasonable to suggest that consumer acceptance of an appliance offering unquestionably greater convenience benefits would be almost assured at an initial price of somewhat less than $300, falling gradually as sales increase to perhaps a level of around $200.

One aspect that must be stressed, however, is the need for operational reliability if consumer acceptance is to be gained. As an appliance that might require housecalls by either plumbers or electricians in the event of malfunction, the potentially high cost of repairs might prove to be a substantial deterrent, even to the relatively affluent suburban resident.

It might be noted that the $300 that is postulated here as being the upper limit for widespread consumer acceptance compares well with the early estimates of feasibility. McKinney and Mahlock,[15] for example, assumed that a pulper-grinder could be built for $240, and Nebiker and Meier[16] assumed a $300 figure for the household grinder in their initial discussion of the feasibility of the wet systems concept.

Production and Sales Costs

On the premise that the refuse grinder would be just another consumer appliance mass produced by the private sector, the difference between retail cost and manufacturing cost becomes very important to the development of realistic specifications; but, unfortunately, production costs are not available from the appliance industry, and only indirect measures for the appliance industry as a whole can be derived. Figures contained in U.S. Industrial Outlook,[18] a government publication, show that for the industry as a whole in 1969, 53.3 percent of the retail price represented manufacturers' costs, with the remaining 46.7 percent added by distribution and retailing. At a retail price of $300, this would imply a manufacturing cost of $159 per unit, which is not much lower than Foster-

Miller's estimate of $180 for the grinder unit at an annual production level of 20,000.[19] But note that all of this assumes that neither storage tank nor replumbing will be necessary.

In the early years of a new appliance, relatively high initial profits and promises of widespread sales can be expected to bring new entrants to the market, as exemplified by several manufacturers who have recently announced their intention of entering the domestic compactor field. The degree of market saturation, generally expressed as the percent of wired homes that have a certain appliance, is still less than 1 percent for compactors, and less than 30 percent for dishwashers and garbage disposers, as shown on Figure 13.

Another factor of some importance to the potential sales picture of a refuse grinder is the percentage of total sales that go into new home construction. Again according to Merchandising Week, 15 percent of all appliance sales were in new home construction and a further 10 percent as part of major home renovations. Unfortunately such figures were not found for individual appliances, but the suspicion that new home construction plays a greater role in the sales of appliances such as disposers or trash compactors appears entirely reasonable.

Installation and Replumbing Costs

The motivation for a reexamination of the Foster-Miller estimates was primarily the need to verify their very high installation cost estimates, which, if even only approximately accurate, would render the wastewater recycling concept practically infeasible.

The costs of installing the grinder, including holding tank, installation and replumbing, as estimated by the plumbing contractor, are shown on Table 5. These estimates assume the use of poly-vinyl-chloride (PVC) piping; and range from $400.00 to $600.00 for new housing and $725.00 to $1,200.00 for existing housing. Foster-Miller estimated that installation costs using PVC ranged from $173 to $275 for new housing and $523 to $1,057 for existing housing, as shown on Table 6. Foster-Miller's cost range using copper pipe is $337 to $494 for new housing and $673 to $1,211 for existing housing. It might be noted that the use of copper piping rather than PVC would be not so much a matter of increased material cost as a matter of increased labor cost. The cost difference of $200.00 between the estimates of Foster-Miller and those of the plumbing contractor is not unexpected in view of the two-year time span between estimates and the nature of the estimates prepared by a plumbing contractor who must obviously include overhead and profit in his bid prices.

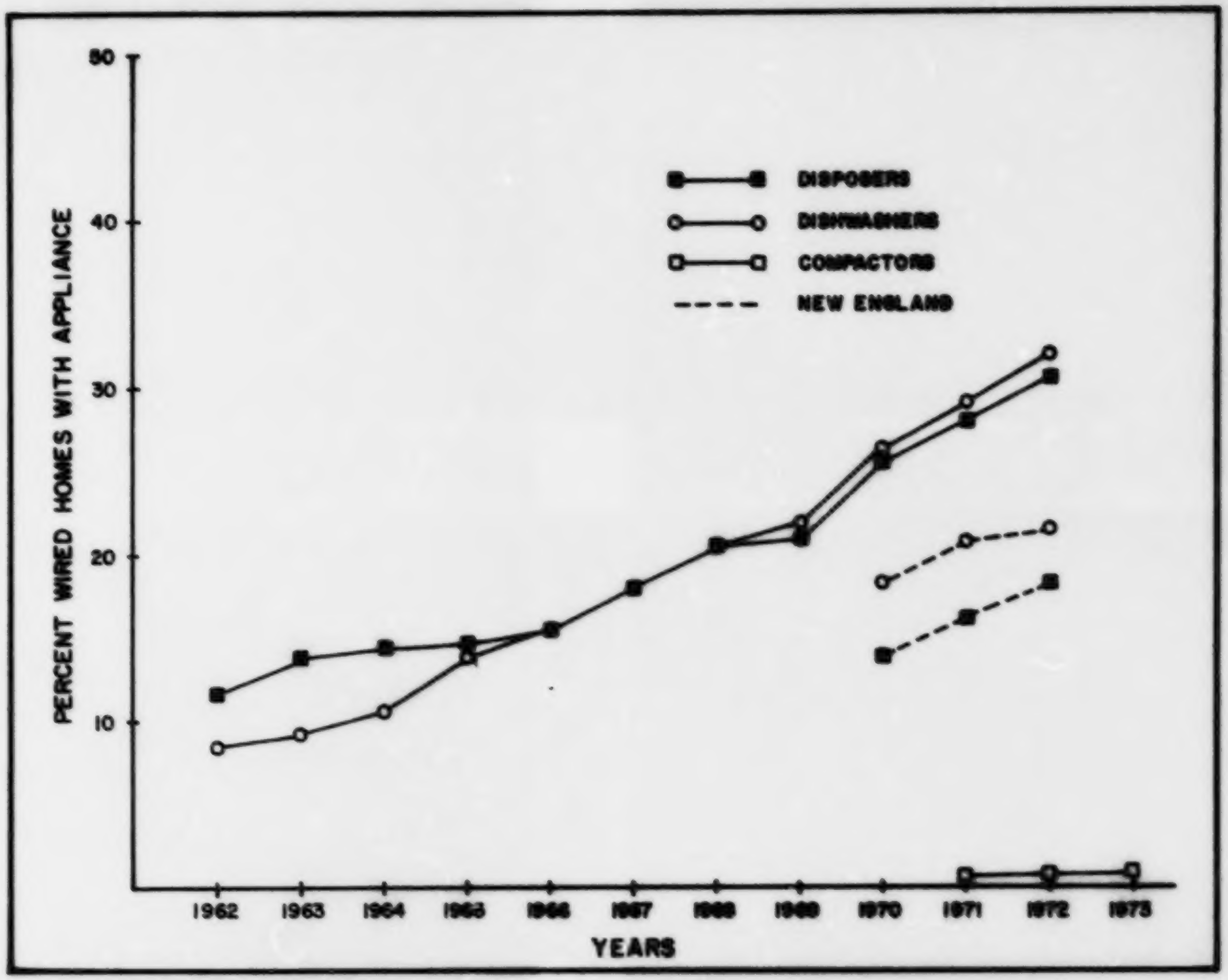

Figure 13: Market saturation of selected domestic appliances

Table 5: Cost estimates for installations of refuse grinding system

Construction Type	Estimated Total Cost
New Construction 2 Story Slab	500.00 - 550.00
New Construction 2 Story Basement	550.00 - 600.00
New Construction 1 Story Slab	400.00 - 450.00
New Construction 1 Story Basement	450.00 - 500.00
Old Construction 2 Story Slab	1300.00 -1400.00
Included in above:	
Excavating concrete floor and patching	150.00
Excavating pit and concrete fill	300.00
Cut and patch and paint walls	175.00
Remove and relay carpets	75.00
Old Construction 2 Story Basement	925.00 -1025.00
Included in above:	
Excavating concrete floor and patching	75.00
Cut and patch and paint walls	175.00
Old Construction 1 Story Slab	1100.00 -1200.00
Included in above:	
Excavating concrete floor and patching	150.00
Excavating pit and concrete fill	300.00
Cut, patch and paint walls	100.00
Remove and relay carpets	75.00
Old Construction 1 Story Basement	725.00 - 825.00
Included in above:	
Excavating concrete floor and patch	75.00
Cut, patch and paint walls	100.00

Table 6: Installation costs for typical residential refuse grinding system

Construction Type	$ Cost Using Copper Pipe	Using PVC Pipe
New Two Story Slab Type	494.00	275.00
New Two Story Basement Type	432.00	215.00
New One Story Slab Type	397.00	233.00
New One Story Basement Type	337.00	173.00
Existing Two Story Slab Type	1,211.00	1,057.00
Existing Two Story Basement Type	799.00	645.00
Existing One Story Slab Type	1,085.00	935.00
Existing One Story Basement Type	673.00	523.00

Source: Fisk and Guzdar, *op. cit.*, p. 100.

Conclusions

If the similarities of the refuse grinder to the garbage grinder, automatic dishwasher, and trash compactor are indeed valid, several conclusions can be drawn from the analysis of recent cost trends:

1. A refuse grinder selling at less than $300.00 would gain consumer acceptance.
2. The cost of the grinder should decrease in the first few years of production because of design improvements, economies of scale and competition.
3. The real cost (inflation adjusted) of the refuse grinder should at worst remain stable, but probably decrease with time.

The conclusions with respect to the feasibility of the wastewater reuse concept appear quite unfavorable. The cost of replumbing existing housing units is clearly prohibitive, and it is even questionable whether the additional plumbing costs in new housing would be acceptable. Although such costs might well be included in the total purchase price, and hence buried in the mortgage payments, the high interest costs thereby incurred have considerable bearing on the real social cost of the wet systems concept, and we shall return to such considerations in Chapter VII.

The presently ascertainable costs of grinding have some very interesting consequences for judging the most likely initial wet systems implementation. Because of their high cost, grinders would inevitably find their first purchasers in the relatively affluent suburbs for installation in single family homes of low residential density. Moreover, such areas are very often characterized by very high conventional collection costs because the low costs of an efficient municipal house-to-house service are not available at such low densities. Many suburban residents spend $1 to $2 a week for a private refuse pick-up, and consequently there may be a real economic benefit in addition to the convenience benefits. This motivation exists far less in the central urban areas where municipal collection, as for example in Springfield, may cost as little as $12.00 per household per year.[20] It could of course be argued that scale economies of grinding could be exploited in central urban areas by virtue of the possibility of a one-per-structure or a one-per-neighborhood installation of grinders, as rationalized in the Phase I report.[21] However, again by reference to the case study area, almost 70 percent of the housing units in Springfield are single-family or duplex residences, for which only a one-per-living unit installation is feasible; and in those areas where the housing density is sufficient for, say, neighborhood grinders, the presence of combined sewers makes the concept inoperable for many years hence.

All the preceding assumes that a grinding concept can be developed that does not require replumbing or a pressurized building connection, yet it is clear that the details of such a concept have yet to be researched. In the absence of such concepts, we may conclude that installation of existing grinding concepts in single-family or duplex housing is economically infeasible. The necessity for further research in this area is obvious, and is again addressed in the concluding chapter.

One alternative that might lessen the impact on the home owner is that of public or quasi-public rather than private wonership. In a manner similar to the leasing of hot water heaters from electric utilities (common in New England), so might refuse grinders be leased from a municipal refuse utility. This utility would also be responsible for maintenance, and could readily arrange for emergency conventional collection during grinder breakdowns. Indeed, in areas of multi-family housing where ownership and maintenance responsibilities are defined only with difficulty, such an arrangement appears mandatory. However, as so eloquently argued by Foster-Miller in their preliminary grinder design report,[22] it is unlikely that anything less than private ownership would engender sufficient respect for the appliance, which in contrast to hotwater heaters, will require continuous care and attention if frequent breakdowns are to be avoided. But again, even definition of the utility concept depends first on the development of a grinding concept of reasonable total cost.

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18. "U.S. Industrial Outlook, 1972," U.S. Bureau of Domestic Commerce, Washington, D.C. One might note that the source for this publication is again Merchandising Week.

19. Fisk, A. T. and A. R. Guzdar , op. cit., p. 100.

20. See below, Chapter III.

21. Meier, P., J. Kühner and C. J. Martel, op. cit.

22. Fisk and Guzdar, op. cit., p. 25.

CHAPTER III

REFUSE COLLECTION

Current Collection Practices

All residential solid waste in Springfield is collected by local government forces. The collection process is divided into once a week pickup of refuse, once a week pickup of garbage, and the pickup of bulky items on an appointment basis. In addition to these year-round operations, a special leaf collection is arranged in October, November and December until snow falls. Leaves gathered by citizens are accepted for collection by the regular refuse collection crews if they are put into containers. The bulk of the leaves is disposed of at the Bondi Island landfill site while a small part is composted for parks. The city of Springfield's collection operation is based on four sections (see Table 7 , each of which is subdivided into five routes corresponding to each work day. On the average, five trucks operate in the first three sections, and six in the fourth section. The trucks on collection routes pick up solid waste from commercial establishments providing the specifications of waste to be collected are not violated. In practice, larger commercial establishments arrange additional private pickup even if they avail themselves of the once-a-week public pickup. What constitutes residential refuse picked up on a regular route, in contrast to bulky items that have to be collected by appointments, is declared in the city's ordinances.[1]

Table 8 shows the operational characteristics of the routes in terms of stops, households, and truck routes, and it can be seen that routes are far from uniform in character. The first three routes of Sections 1 and 2 seem to be made up predominantly of multidwelling units; Section 4 and all but route three of Section 3 are very suburban in character with predominantly single family housing. Subsequent interpretations of solid waste generation rates reveal strong correlations between the households per stop (HH/stop) ratio and the seasonal variation of the refuse generation.

In addition to these residential routes, the downtown business district is serviced by public collection once a week, on Friday night. Two trucks of the department are used for this special commercial route.

As mentioned above, the collection of garbage is handled separately. Nine truck routes are set up to service the city. But according to garbage collection crews, not every household has a pickup. The installation of garbage grinders in homes has increased significantly in recent years.[2] This development, together with the fact that many residents also put some garbage into the refuse,[3] is the reason for the partial pickups and the resulting relatively small amount of garbage collected by the city forces. The Division of Solid Waste wants to phase out the separate garbage collection in the fall of 1973 and switch to a combined collection system.[4]

Table 7: Springfield, Massachusetts - solid waste collection sections

Section	Portion of the City Served
1	Northwest corner; bounded roughly by the Connecticut River on the west, the city limits on the north, St. James Street on the east, and State Street to the south. Includes Census Tracts 8003-8010, 8012, 8013. Neighborhoods: Brightwood, Van Horn Park, "The Campgrounds."
2	Southwest corner; bounded by the Connecticut on the west, State Street on the north, Belmont Street, Sumner Street and Wilbraham Avenue on the east, and the city limit to the south. Includes Census Tracts 8011.2, 8012, 8013, 8018-8023 and 8026. Neighborhoods: South End, Southern Downtown area, Forest Park.
3	Southcentral; bounded by north-south extension of Wilbraham Avenue on the west, Wilbraham Road on the north, Parker Street on the east and the city limit on the south. Includes Census Tracts 8014, 8016.01, 8017, 8024, 8025. Neighborhoods: Watershop Ponds area, Blunt Park.
4	Western; horseshoe shaped, bounded on the north, east and south by the city limits. Includes Census Tracts 8001, 8002, 8015.2, 8015.3, 8016.02-8016.05. Neighborhoods: Indian Orchard, Sixteen Acres.

Table 8: Operational characteristics of collection routes

SECTION 1

Routes	# Stops	# HH	HH/ Stop	# Trucks
1 (Mon.)	1079	2689	2.49	5
2 (Tu.)	1214	2729	2.24	5
3 (Wed.)	1397	2860	2.04	5
4 (Th.)	1828	2153	1.17	5
5 (Fri.)	1446	2166	1.49	5

SECTION 2

Routes	# Stops	# HH	HH/ Stop	# Trucks
1 (Mon.)	820	3520	4.30	5
2 (Tu.)	1323	2957	2.23	5
3 (Wed.)	1500	2866	1.91	5
4 (Th.)	1545	2715	1.75	5
5 (Fri.)	1124	2539	2.25	5

SECTION 3

Routes	# Stops	# HH	HH/ Stop	# Trucks
1 (Mon.)	1488	1961	1.31	5
2 (Tu.)	1788	2233	1.24	5
3 (Wed.)	1892	3057	1.61	5
4 (Th.)	1894	2186	1.15	5
5 (Fri.)	1709	1709	1.00	5

SECTION 4

Routes	# Stops	# HH	HH/ Stop	# Trucks
1 (Mon.)	2325	3104	1.33	6
2 (Tu.)	2606	2608	1.00	6
3 (Wed.)	2757	2968	1.07	6
4 (Th.)	2755	2960	1.07	6
5 (Fri.)	2575	2575	1.00	6

Bulky metal and nonmetal items are picked up by appointment. But observations showed that some bulky items were also accepted by the regular refuse collection crews and that many people do not know about the possible arrangements.[5]

Current Disposal Practices

With the exception of garbage, bulky metal items, and small amounts of newspaper (that are separated and bundled by households, picked up by the collection trucks and sold to a waste paper dealer), the solid wastes of Springfield and the town of Agawam are deposited in the landfill on Bondi Island and covered with gravel and other earth.

The landfill area on Bondi Island has been city property for more than 50 years, and was not bought specifically for the landfilling operation. Because the site is located in the town of Agawam, that town is also permitted use of the landfill, and the fee Agawam pays Springfield to use the site now just offsets the property taxes Springfield pays to Agawam. In 1940, the first wastewater treatment plant was constructed on Bondi Island; the existing primary treatment facilities are about to be expanded to secondary treatment.[6] The sludge from the primary treatment plant is also disposed of here. Because the disposal of all material except garbage is allowed at the landfill site, the city continues the separate garbage collection and transfers the garbage to the Martin Brothers' piggery trucks at the landfilling site. In December 1972, the "Board of Appeals" of Agawam granted Springfield a permit to dump garbage on Bondi Island, but Agawam's planning board subsequently challenged the permit and filed suit in Springfield Superior Court. The suit is expected by most observers to be unsuccessful. Agawam also changed its governmental form at that time, which introduced an additional factor of uncertainty. The above notwithstanding, the Division of Solid Waste still expects to phase out the separate garbage collection in the fall, because the separate collection of garbage is very expensive, and there is no garbage disposal opportunity in the vicinity. The annual revenue of $1,000 received from the piggery does not reduce the cost significantly.

The cover material, mainly gravel, is purchased by the division from a contractor for approximately $2/cu yd ($2.19/cu m). Western Massachusetts Electric has tried to sell their flyash to the city for $1.50/cu yd ($1.64/cu m); but the city has not agreed to this price, since only a few years ago, Western Mass. Electric used to pay $.40/cu yd ($.44/cu m) to a contractor to get rid of the ash. But since the landfill regulations became more stringent, and cover material has become an important resource, Western Mass. Electric has tried to gain a profit from their flyash. Because of the current disagreement on the price, Western Mass. Electric still stores the flyash on their own premises. However, an agreement can be expected in the long run, since on one hand the city can restrict the utility by strict enforcement of ash storage ordinances, and on the other hand, the gravel purchase arrangements will become increasingly expensive to the extent of becoming a significant item in the division's budget.

Because the landfill has groundwater contact in times of a high water table, a long run usage of the landfill would appear to be precluded in view of the expectation of more strict enforcement procedures in the near future.

The landfill on Bondi Island has also provided for the disposal of solid wastes by private contractors. In 1972, the total amount of privately collected solid waste approached 106,631 cubic yards (81,466 cu m), weighing approximately 17,532 tons (15,902 kkg). Vehicles arriving at the site are charged from $1.00 to $10.00, according to maximum truck capacity.

The revenue received for the disposal of privately collected material was $32,612.00 in 1972. The peak rate of such deliveries occurs in March, whereas the fall months' deliveries are relatively low. This would indicate that the fall peak of garden waste is largely taken care of by the public collection.

Resource Recovery

The city government is very much in favor of resource recovery activities, since resource recovery can provide some revenues, for instance by the sale of bundled newspaper, and some imputed benefits by savings in disposal space. Mainly in view of the latter benefits, resource recovery from refuse has gained significance in many municipalities as the selection of a new landfill site has become such a sensitive political issue.

The city of Springfield ships the bulky metal items that are picked up by appointment to the scrap dealer, Harry Goodman, Inc. There is no revenue on the metal scrap, but the city received some $3,950 for the recycling of 648.57 tons (588.25 kkg) of newspaper in 1972. Because the demand for secondhand paper increased dramatically in the last months, primarily in response to the papermill strike in Canada, Mr. Goodman has again tried to encourage the city to put more official efforts into recycling. The city was very intensively involved in recycling activities two years ago, at which time the city cooperated with a citizen group's[7] resource recovery efforts by offering city trucks and manpower. The city's contribution, however, was subsequently terminated in view of high costs. It might also be noted that newspapers are not collected only by the city, but also by some dealers that have long been in the secondhand material business.[8]

Manpower and Equipment

Municipal collection forces use both packer-body and watertight body vehicles. According to a recent American Public Works Association (APWA) questionnaire, average conditions see 6 of 36 20-cu yd compactor trucks and 1 of 3 30-cu yd enclosed noncompactor trucks on standby. The average number of men on collection routes is 34 drivers and 70 collectors on regular duty, plus 7 drivers and 15 collectors on vacation and sick leave.

The average number of men in the collection crews is three, including the driver. All employees are under Civil Service regulations, and have been organized in a nationally affiliated union since 1968. An incentive system exists for the collection routes, with the "daily route" method permitting every crew to go home upon the satisfactory completion of their assigned routes, resulting in an average work day of 6.5 to 7 hours. The system is not varied with the season, so that relatively low winter and summer loads are contrasted with high spring and fall loads.

The schedule of hourly wages is shown on Table 9. The overtime rate for hours in excess of the basic 40 hour week is 1.5 times the regular rate.

Table 9: Schedule of hourly wages

	Minimum	Maximum	Approx. Cost of Fringe Benefits/hr.
Drivers	$ 3.62/hr.	$ 3.62/hr.	$.75
Collectors	$ 2.67/hr.	$ 3.02/hr.	information not available
Foreman	$144.60/wk.	$173.90/wk.	

Prior to 1968, wages rose at irregular intervals every 2 to 3 years. But since the unionization agreement of 1968, a more continuous rise has taken place. A retroactive increase of 5 percent to January 1 is expected for 1973; further raises, each of 5 percent, are anticipated for 1974 and 1975. Although officials feel unionization has had the effect of raising wages, wage increases accelerated throughout the economy in the late 1960's, so it is not really clear what independent effect the unions have had. No labor disputes and strikes have occurred in the last five years. The contract with the union includes a variety of points that greatly influence the system; for example, it determines that "excluding work of an emergency nature, no outside work shall be performed in severe or snow or other weather conditions of such degree that work cannot reasonably be performed."

The reader may recall the threat of labor disputes in Boston caused by the intention of the city to reduce the frequency of collection in some quarters and hence to lay off some personnel.[9] The Division of Solid

Waste of Springfield does not anticipate any similar difficulties when the separate garbage collection is dropped in the fall. Because the division feels it can profitably use them in other jobs which the current budget does not provide for (the budget has been tight both on new positions and on overtime), no lay-offs are anticipated. Indeed, money has been available for equipment purchases for streetcleaning, but because no positions for operating and support personnel were available, these opportunities could not be exploited.

The equipment of the Division of Solid Waste varies greatly in age and performance. In recent years, many old collection trucks dating from 1961 were phased out. Approximately 15 new packers were purchased in the last three years; it is planned to continue to purchase four to seven new collection vehicles every year. The oldest trucks currently in operation date from 1966 and 1967. They are mostly used on standby or as additional forces in times of heavy solid waste generation.

The division has the internal regulation that the same driver is always responsible for the same truck; and it is considered that this has reduced overall down time. When a driver is on vacation (2 weeks, which the division tries to give in the summer), nobody else drives his collection vehicle, except in emergency cases. This policy may at first appear strange considering the loss of efficiency when a new truck is not fully utilized, but the benefits in terms of better year-round performance (less required maintenance for breakdowns) seem to justify the measure. The initiation of the city's own preventive maintenance program has permitted nighttime repairs, with the maintenance shift working from 3:00 to 12:00 P.M.

The equipment for the landfill operations consists of a variety of earthmoving machines; the largest being a 70-ton rubber wheel compactor that is leased by the city for $25/hr and operating approximately 60 hrs/wk. The city considered the purchase of a similar piece of equipment, but found leasing more economical, especially in view of the back up machine provided by the contractor for an additional $2.50/hr in case of breakdowns. Until recently, a scraper was leased in the same way, but has now been taken over by the city. The money for leasing the equipment is requested and provided in the yearly budget. Every year, each division's head submits his budget request to the Superintendent of the Public Works Department, who coordinates all the requests to the departmental budget request that is submitted to the Mayor.

Yearly Costs of Solid Waste Management

Per Capita and Per Ton Costs. The total operating expenditures of the Division of Solid Waste[11] are summarized for the years 1970 to 1972 in Table 10. Despite the escalation of inflation, the total operating costs have been reduced by approximately $60,000. The labor costs increased by 4.47 percent, but of the other significant items, the costs for hired equipment decreased by 27 percent and the overhead by 6.82

Table 10: Operating expenditures of the Division of Solid Waste from 1970 to 1972

	1972	1971	1970
Labor	720,670.67	736,556.24	737,664.48
Hired Equipment	88,329.60	97,949.80	122,261.49
Material	23,207.14	41,305.99	40,093.89
Other Direct Charges	12,374.13	8,974.83	40,623.72
Overhead	236,322.50	246,769.00	253,619.80
City Trucks	263.45	193.35	845.33
City Equipment	109,445.00	113,509.85	107,544.00
TOTAL COST	1,240,612.49	1,245,299.06	1,302,652,71

percent. However, the capital amortization costs of trucks and other equipment do not seem to be represented sufficiently. Fringe benefits and depreciation show up under overhead with $1/hr, which appears to be fairly low. In order to express the influence of amortization of capital costs on the possible implementation schedule of the wet transport system, the total value of capital used by the Division of Solid Waste Disposal should be known, especially that capital invested in collection vehicles. Their useful economic life is usually assessed at 5 years.

The total costs of $1,240,612.49 in 1972 can be converted to per capita and per ton figures. The 1972 per capita cost for collection and disposal is $7.56 and the cost per ton received at Bondi Island is $14.28 (see Table 11). These global averages can be refined to give more insight. The revenue from the sale of garbage and newspaper and from the landfilling on Bondi Island by private contractors reduces the per capita cost to $7.30. The revenue of $32,612 for the privately collected refuse, which amounted to 12,500 tons (11,338 kkg) has implied disposal costs of $2.60/ton ($2.88/kkg). The total costs of the Bondi Island disposal site ($193,899.28) minus the revenue of $32,612, divided by 69,999 tons (63,490 kkg) (74,151.9 tons (67,256 kkg) minus garbage minus metallic bulky items) give a disposal cost figure of approximately $2.30 per ton ($2.54/kkg). Assuming an average collection rate of 2.26 lbs/cap/day (1.03 kg/cap/day), the average disposal cost (refuse and nonmetallic bulk) per capita/year is:

$$\frac{\$2.30 \times 2.26 \times 365}{2000} = \$.95/\text{cap/yr}$$

Table 11: Summary sheet of the Division of Solid Waste for 1972

Work Performed	1972 Expenditures	Refuse Collected (tons)	Refuse Received at B.I. (tons)	Revenues Received
Collection of Ashes & Refuse				
Daily -	$ 612,670	67,119	67,997	-
Friday Night -	8,272	877	-	-
Collection of Garbage	321,988	3,286	-	$ 1,000
Collection of Nonmetallic Bulk	{ 44,138	866	-	-
Collection of Metallic Bulk		1,353	1,353	-
Collection of Newspaper for Recycling	5,493	648	-	3,968
Sanitary Landfill Disposal Site	193,899	-	86,883[b]	32,612
Servicemen	51,572	-	-	-
Maintenance of Grounds	2,540	-	-	-
Hauling Derelict Automobiles	38	-	-	-
TOTALS	$1,240,612[a]	74,151		$37,580

[a] Total A&R Expenditures include overhead figures not reflected in completed 1972 budget.

[b] Combined total of city and private deliveries.

The average collection costs would be (see Table 11):

$$\frac{\$612,670.00}{67,119} = \$9.12/\text{ton } (\$10.06/\text{kkg})$$

or

$$\frac{\$9.12 \times 2.26 \times 365}{2000} = \$3.76/\text{cap/yr}$$

for the municipal refuse collection and:

$$\frac{\$8,272}{877} = \$9.43/\text{ton } (\$10.39/\text{metric ton})$$

for the downtown business district collection on Friday night. The downtown collection has a per capita impact of:

$$\frac{\$8,272}{163,905} = \$0.05/\text{cap/yr}$$

which does not significantly influence the total per capita cost.

The per capita refuse collection cost is low compared to figures from other cities; for example, Partridge and Harrington[12] investigated Boston's collection process and reported a range of $4.55 to $10.30/cap/yr and an average of $7.20/cap in 1969 costs. But the per ton refuse collection cost appears to be quite typical if contrasted to the mid-60's figures of Stone,[13] who reports median values of $10.64/ton ($11.73/kkg) and average values of $10.20/ton ($11.24/kkg) for cities with populations between 100 and 500 thousand inhabitants. The main reason for the low per capita collection costs is the low per capita generation rate. Similarly, Clark[14] made some generalizations by assuming a daily per capita generation rate of 3 lbs (1.36 kg), and concluded: "Assuming that the collection cost of solid waste is approximately $10 per ton..., $25 per annum would be a reasonable collection service charge for a family of four." Although the per ton costs are similar, the charge for Springfield would only amount to approximately $15 per family. The per capita disposal costs of $.95 are very low compared to national averages. Clearly, it has to be expected that the costs will rise significantly with stronger enforcement of the landfill operating regulations, and at least approach the average figure of $3.00 per capita/year.[15] In addition, the present cost figures for Springfield appear to be low because inadequate amortization of equipment is included.

The collection of garbage, as reported by the Division of Solid Waste, is reported as $1.96/cap/yr and $9.80/ton (exclusive of the yearly revenue of $1,000). To evaluate these figures is very difficult, since, as explained below, approximately 50 percent of the households have garbage grinders and, in addition, many families do not put their garbage into a separate container, but into the rubbish. The intention of the city to abolish the separate collection seems to be justified in the light of these figures.

Costs per Household and Per Stop: The average city-wide residential collection cost per household (HH) anc cost per stop are calcualted with the data provided by the Division of Solid Waste as follows:

$$\frac{\$612,670}{52,551} = \$11.66/HH$$

$$\frac{\$612,670}{35,065} = \$17.48/stop$$

Assuming a uniform distribution over the year and across the city, the collection costs of each section in dependence of the number of stops (X) and the number of households (Y) can be calculated as follows:

	# Stops	X ($)	# HH	Y ($)
Section 1	6,964	$121,730	12,593	$146,834
Section 2	6,312	$110,333	14,597	$170,201
Section 3	8,771	$153,317	11,146	$129,962
Section 4	13,018	$227,554	14,215	$165,746

where X = # of stops x $17.48/stop, and Y = # of HH x $11.66/HH

The results are quite interesting: in terms of cost as a function of the number of households, there is little variation between sections, and in particular, the expected difference in collection costs between core and suburban areas does not appear. However, the cost as a function of the number of stops reveals a clear shift of the major costs to the suburban areas characterized by their high ratios of transport to collection time (see section on collection efficiency), and their longer travel distances to the landfill. The validity of the assumption of a uniform collection cost distribution over the year and the city can thus be questioned. The distribution of overtime costs gives some evidence. According to the division's information,[16] the total overtime costs in 1972 amount to $68,373, which is 5.5 percent of the total 1972 expenditure of $1,240,619 and 8.8 percent of the 1972 labor costs (see Table 12).

One third of the overtime costs arise in the weeks that have holidays, since the division tries to make up for the loss of the holidays in the following two days. Since the collection rate has seasonal peaks in spring and fall, it may be concluded that a substantial part of overtime costs due to holidays arises in these two seasons. The overtime costs in the disposal area should correspond to the collection overtimes. Furthermore, overtime pay became necessary in the particularly heavy collection

Table 12: Significant items having caused overtime in 1972

Reason	Expenditure	% of Total Overtime Cost
Collection after holidays	$23,000	33.6
Friday night (downtown) collection	7,900	11.5
Overtime due to breakdowns and exceptional demand (leaf Collection not included)	8,800	12.8
Leaf collection (incurred only between Oct. 28 and Thanksgiving)	1,700	2.4
Disposal area	15,600	22.8
Garage (A&R personnel only)	7,300	10.6
Miscellaneous	4,073	6.3
TOTAL	$68,373	100%

weeks of April 22nd and 29th with $900 and $700, respectively, of overtime costs, as well as in the two following weeks with $150 and $200, respectively; the week of June 1st brought another heavy burden ($300). A week with overtime pay not because of a heavy generation rate, but because of bad weather conditions, was the week of January 1, 1972.

Moreover, the total cost distribution may not be as uniform as labor costs. It seems that the incentive system has been set up in such a way that enough buffer time is given for seasonal and daily fluctuations of the solid waste collection rate. That makes the labor costs (approximately 62 percent of the total yearly expenditure) quite uniform; but the nonlabor costs on hired and city equipment, maintenance, and material must necessarily be influenced by the seasonal variation. Due to the lack of refined expenditure statistics, the assumption of cost uniformity over the year is thus a bold one. Spatial uniformity appears to be quite unlikely since each stop is of a different characteristic in terms of traffic impact, number of households, socioeconomic factors, etc. Also, according to qualitative statements of division officials, section four provides the most time-consuming routes; it has the most stops, but not the most households. Therefore, the rough assumption is made that the costs per stop can be uniformly distributed over all sections, implying that the larger number of HH/stop in the core areas is compensated by the longer travel time between stops and to the landfill in suburban areas. Based on this justification of uniformity, the resulting costs per route as a function of the route's number of stops are presented in Table 13.

Table 13: Cost of all collection routes as function of # of stops

Section 1 Collection Route	# Stops	Cost (Stops)
1 (Mon.)	1,079	$ 18,860.92
2 (Tu.)	1,214	21,220.72
3 (Wed.)	1,397	24,419.56
4 (Th.)	1,828	31,953.44
5 (Fri.)	1,446	25,276.08
		$121,750.72

Section 2 Collection Route	# Stops	Cost (Stops)
1 (Mon.)	820	$ 14,333.60
2 (Tu.)	1,323	23,126.04
3 (Wed.)	1,500	26,220.00
4 (Th.)	1,545	27,006.60
5 (Fri.)	1,124	19,647.52
		$110,333.76

Section 3 Collection Route	# Stops	Cost (Stops)
1. (Mon.)	1,488	$ 26,010.24
2 (Tu.)	1,788	31,254.24
3 (Wed.)	1,500	26,220.00
4 (Th.)	1,894	33,107.12
5 (Fri.)	1,709	29,873.32
		$146,464.92

Section 4 Collection Route	# Stops	Cost (Stops)
1 (Mon.)	2,325	$ 40,641.00
2 (Tu.)	2,606	45,552.88
3 (Wed.)	2,757	48,192.36
4 (Th.)	2,755	48,157.40
5 (Fri.)	2,575	45,011.00
		$227,554.64

Generation Rate and Composition of the Residential Refuse

The determination of the refuse generation and collection rates and the composition of the residential refuse is crucial to our assessment of the feasibility of a wet systems implementation. Three different sources were investigated to establish this information:

1. Total solid waste generation of Springfield (number of loads that arrived at the sanitary landfill on Bondi Island).
2. The surveys conducted by the division of solid waste in 1972 (weighing trucks of each route in each section, once in each season).
3. Four truck route investigations by Curran Associates (counting the cans, bags and miscellaneous materials that were collected by the city trucks).

Generation Rate. The 1972 city-wide average residential refuse generation rate was established as 2.56 lb/cap/day, which is well in the range reported in the literature, and not entirely inconsistent with the 2.25 lb/cap/day used in the Phase I report. Any error associated with this figure would tend to be conservative, as it includes such commercial refuse as is picked up as part of the normal residential collection routes. The approximate contribution of individual components were established as follows:

Bulky refuse, collected by appointment	0.07 lb/cap/day
Separately collected garbage	0.11
Garbage now ground to sewer	0.11
Separately collected newspaper	0.01
All other components (regular collection)	2.26
	2.56 lb/cap/day

Seasonal Variations. The seasonal variation in the refuse generation rate is portrayed in Table 14. These figures are based on a sample survey conducted by the Division of Solid Waste, and are presented in terms of lb/household/week. The 49.44 lb/HH/wk shown as the year-round average corresponds to a rate of 2.27 lb/cap/day, which compares well with the previously derived figure of 2.26 lb/cap/day based on annual totals. Since each mean value for each section is based on 5 or 6 routes, the standard deviations for each section and each season are also given. Inspection of these data show a fall generation rate that is almost double the winter rate, with a second peak in spring. Moreover, inspection of the raw data showed that the sectional averages hide considerable variation among individual routes.

Composition. The composition of the refuse generated, by season, is given on Table 15. Composition of the refuse presently collected is somewhat different, due to existing garbage grinders and the separate

Table 14: Summary of sectional and seasonal values

Section	Month	WINTER Mean (lbs/HH)	WINTER SD (lbs/HH)	Month	SPRING Mean (lbs/HH)	SPRING SD (lbs/HH)
I	Feb	36.16	3.66	Apr.	52.20	7.96
II	Jan.	30.37	2.67	Apr.	46.51	9.31
III	Feb.	32.44	1.99	Apr.	62.51	7.01
IV	Feb-Mar	36.61	5.33	Apr.	54.96	5.22
Seasonal avg.		33.88			54.04	
Seasonal SD			8.34			9.04

Section	Month	SUMMER Mean (lbs/HH)	SUMMER SD (lbs/HH)	Month	FALL Mean (lbs/HH)	FALL SD (lbs/HH)	YEAR AROUND Average (lbs/HH)	YEAR AROUND SD
I	July	42.70	2.83	Nov.	61.20	11.58	48.06	6.86
II	July	40.11	9.17	Nov.	47.36	9.25	41.08	5.86
III	July	52.37	4.50	Oct-Nov	71.74	17.07	54.76	7.82
IV	July	49.72	3.98	Nov.	74.20	18.54	53.87	7.69
Seasonal avg.		46.22			63.62		49.44	
Seasonal SD			7.30			17.53		

Table 15: Mean weight percentages of the SW components on a seasonal, city-wide basis

	Winter (%)	Spring (%)	Summer (%)	Fall (%)
Glass	10.54	6.82	7.95	5.96
Metal	10.87	7.03	8.20	6.14
Paper	55.16	35.76	41.59	31.21
Plastics	1.52	.98	1.15	.86
Leather and Rubber	2.07	1.34	1.56	1.17
Textiles	2.83	1.83	2.13	1.60
Wood	3.15	2.04	2.38	1.78
Garbage	12.0	7.76	9.05	6.78
Miscellaneous	1.85	26.44	5.00	5.00
Garden Waste	-	10.00	21.00	39.50
	100.00	100.00	100.00	100.00

garbage collection. The basis for these figures are national averages, modified to the extent that our observations and inferences allowed. Because direct measurements of composition are not available, there is a higher degree of uncertainty associated with these figures than with others presented in the analysis. The influence of the fall peak of leaves, and the spring attic cleaning is clearly reflected in the composition as shown on Table 15. Again it should be noted that the city-wide averages hide considerable variations among sections and routes; but in the absence of actual data, a derivation of composition for individual sections and routes would be quite speculative. It is recognized, however, that such detailed knowledge would be necessary before collection routes for nongrindables could be planned in detail.

Allocation and Performance of Municipal Collection Service

The city is divided into four sections, comprised of five truck routes in Sections 1 to 3 and six truck routes in Section 4. Each section has one foreman, who controls the operation of his section by car and shifts crews between truck routes in the case of breakdowns and exceptionally high collection rates. All pickups are from the curbside; no backyard service is provided. The most common truck in operation is a 20-cubic yard rear loading vehicle, although some equally sized trucks with continuous compaction have been recently introduced.

The actual collection operation starts in the morning at about 7:30 a.m. An earlier start, that would benefit the loaders in the hot summer, is prevented by possible compliants about noise disturbances. In general, the trucks make two trips to the landfill in order to fulfill their assignments. Usually, the crews do not take extra breaks for lunch and breakfast in order to finish as fast as possible, and the end of the assignment is generally reached around 2-3 p.m. As mentioned above, if breakdowns or particularly heavy collection requirements occur on a route, and cause a crew to fall behind schedule, crews from other routes which have already finished will be moved in for support. Complaints about those assignments are infrequent, since every crew is aware that they can end up in the same situation. According to the Commonwealth of Massachusetts regulations, the driver is not permitted to help loading; the engine has to be stopped before the driver leaves the truck. But that is not possible on the collection route since the compactor is also driven by the engine. Compaction occurs frequently; and generally after the pickup of four households of rubbish (see below). In addition, compaction is not possible during the haul from one stop to the next. Therefore, the new continuously compacting trucks could be used very efficiently in the suburban areas, where driving from stop to stop constitutes much of the total time. The use of bags instead of cans would provide an additional increase in time savings.

The last major upgrading of routes occurred in 1971. No changes of routes are made during seasons, although, as noted previously, it is very obvious that the routes are differently influenced by the seasonal fluctuations. Incentives to adjust routes more to operational needs is recognized by the DSW, but the effects of being understaffed have become substantial following a cut in the division's allowance for overtime. It appeared to be useful to find some rational means by which to classify the routes; this is particularly important in order to judge today's route system under the aspect of possible reduction of collection frequency for the nongrindables.

Over the last 10 years, several detailed studies have tried to tackle the question of efficiency in collection. Wersan, et al.,[17] pointed out the influence of the frequency of collection, the container location and the type of truck. Their measure of efficiency is expressed as man-minutes per ton and man-minutes per ton-mile; the latter yields the "so-called haul-efficiency." Quon, et al.,[18] investigated Chicago's collection operation by analyzing worksheets that were filled out by the drivers of the collection vehicles. They showed, for instance, that the age of the truck and routes of load (first, second or third trip during the working day) impose a sizable influence on the work efficiency. Clark reports in various publications[19] some additional factors that influence the efficiency of solid waste collection crews and defines different measurements that could reflect the efficiency; for example, average service time per unit, calculated by dividing the total productive time required to service the housing units by the number of units, is such a measurement.

Since our sampled data are of limited value, it was decided to summarize the available facts and to make some standard calculations in order to derive some judgments about the situation. Table 16 provides some results of these efforts. The main assumptions made for the calculations were that the average haul-time from stop to stop is 8 seconds (.133 min) and that compaction takes place after loading the refuse of four households and lasts approximately 30 seconds. Although these assumptions are based on our observations during the field trip, our survey was not conducted as a rigorous time and motion study. Thus, the calculation for the first trip of Route 1 in Section 1 is as follows. Dividing the gross time (1st stop to last stop) by the number of households and stops yields the gross unit values in sec/HH (36.1) and sec/stop (21.3), respectively. The net pickup time is obtained by subtracting the haul and compaction time from the gross time (138.0 - 28.0 - 15.4 = 94.6 min). The corresponding times are 24.7 sec/HH and 48.9 sec/stop. These calculations reveal that 20.2 percent of the gross time is taken up by collection and 11.1 percent by haul between stops. The per capita per day collection rate is 1.76 lbs (.8 kg) derived from the total tons per trip (see Table 16).

As mentioned above, the number "man-min/ton" is a traditional measurement of efficiency; because of the limitation of the data, the number was calculated solely from the net pickup times. Usually, this figure is derived from the total collection time per trip. The unit "ton per hour" is found by dividing the tons collected on the trip by the gross time. The results from "man-min/ton" describe the efficiency of the pickup, whereas the latter is indicative of the efficiency of the collection process on that trip excluding the hauling between landfill, garage and route. The next column indicates the end of the collection in the regularly assigned areas, which shows quite surpirsing results for the first two routes. The last column gives an idea of the time spent for one-way hauling between the landfill and the collection route.

The net pickup times per household appear to be low, but measurements of the actual pickup movements confirm these rates. The pickup rates on trip 2 of route 1 in section 2 seem to be very small; but the per capita generation rate of refuse (1.4 lbs/cap/day or .64 kg/cap/day) is also exceptionally low, and, in addition, the household per stop ratio is very high. Furthermore, the number of persons/household is very low (2.3), so that it can be assumed that only one container per household has to be picked up. Considering these facts, the average pickup time per household of 11.6 seconds is not unreasonable.

It should be noted that on most routes, the time wasted by compaction is much larger than the time spent for hauling between stops; but on the suburban route (household to stop ratio = 1), the haul time is larger. It is thus clearly underlined that a continuously compacting truck would be of considerable advantage on these suburban routes. The results of the Kensington Route (see Table 16) show how efficient a continuously compacting truck can work (see column on man-min/ton). The slightly

Table 16: Efficiency calculations for sampled routes

ROUTE OBSERVED CENSUS TRACT	TRIP	$\frac{HH}{STOP}$	HH/STOP	GROSS TIME FROM FIRST STOP TO THE LAST (min.)	GROSS TIME SEC/HH / GROSS TIME SEC/STOP	TOTAL COMPACTION TIME (min/day)	TOTAL HAUL TIME BETWEEN STOPS (min/day)	NET PICKUP TIME (min/day)
Brightwood Section 1	1	$\frac{229}{116}$	1.97	138	$\frac{36.1}{71.3}$	28	15.4	94.6
8007	2	$\frac{183}{112}$	1.64	89	$\frac{29.2}{47.6}$	23	14.9	51.1
Oswego Section 2	1	$\frac{314}{70}$	4.49	146	$\frac{27.84}{125}$	39.3	9.3	97.4
8020	2	$\frac{190}{18}$	10.61	63	$\frac{19.7}{210}$	23.8	2.4	36.9
Kensington Section 2	1	$\frac{226}{119}$	1.9	96	$\frac{25.44}{48.5}$		15.8	80.2
8023	2	$\frac{266}{140}$	1.9	110	$\frac{24.8}{47}$		18.6	91.4
Backup Duty	3	$\frac{97}{42}$	2.3	57	$\frac{35.2}{81.4}$		5.6	51.4
Sixteen Acres Section 4	1	$\frac{264}{264}$	1.0	172	$\frac{39.1}{39.1}$	33	35.1	103.9
8016								

ROUTE OBSERVED CENSUS TRACT	NET TIME SEC/HH / NET TIME SEC/STOP	% COMPACTION TIME	% HAUL TIME BETWEEN STOPS	LBS/CAP-DAY	TONS/TRUCK-TRIP	MAN-MIN. PER TON (INCLUDES DRIVER)[a]	TON/HR. (ON GROSS TIME BASIS)	TIME OF DAY AT END OF ASSIGNED ROUTE[b]	ONE-WAY HAUL TIME TO LAND-FILL (min)
Brightwood Section 1	$\frac{24.7}{48.9}$	20.2	11.1	1.76	4.949	83.65	2.15	11:58	10
8007	$\frac{16.7}{27.4}$	51.6	16.7	1.90	4.270	62.53	2.87		
Oswego Section 2	$\frac{18.6}{83.5}$	26.9	6.3	2.20	5.550	78.92	2.28	11:35	7
8020	$\frac{11.6}{122.8}$	37.7	3.8	1.40	2.330	81.12	2.22		
Kensington Section 2	$\frac{21.0}{40.4}$	-	16.4	2.36	5.460	52.75	3.41	1:45	11
8023	$\frac{20.6}{39.1}$	-	16.9	2.67	7.290	45.27	3.97		
Backup Duty	$\frac{31.7}{73.4}$	-	9.8	-	-	-	-		
Sixteen Acres Section 4	$\frac{23.6}{23.6}$	19.1	20.4	2.05	7.02	73.5	2.45	-	25
8016.04									

[a] Net Pickup Time

[b] Not Including Trip to Landfill

higher pickup time per household is probably due to a fatigue factor explainable by the fact that the crews have much less time to relax than the crews with trucks which have to compact for 30 seconds after approximately every 30 seconds of work.

Planning for the Future of the Conventional System

Many components influence the outcome of the planning process for the future of the conventional Solid Waste Management System. The major considerations are:

1. The future total and per capita generation rate of residential solid waste as well as the differential growth of the various components.
2. Technological and operational changes of the collection process to increase the crews' productivity as well as diversion of certain categories from the collection process through garbage or refuse grinding.
3. Technological and operational advancements of solid waste disposal facilities.
4. Economic, institutional and legal issues, as regionalization of waste hnadling and more stringent antipollution standards are initiated.
5. Educational influences on the population's willingness to pay for solid waste management.

The economic and financial development of the region as a whole will have an intrinsic influence on the population's ability to pay. Since this effect is independent of the system under investigation, it is not considered here in detail.

Future Generation Rates. As mentioned in the Phase I report of this study,[20] there exists considerable confusion about the actual rate of residential solid waste generation, a confusion that is also present in the estimates of the proportion of the different categories. Of the few studies that have attempted quantitative analysis, that of Niessen and Chansky[21] appears most relevant to our discussion. This study attempted to project the expected differential growth of 10 major categories of solid waste on an average national basis. Such results have their limitations since local averages differ from national averages because of a variety of technical, socioeconomic and institutional reasons and because of the differences in the collection process. Their investigations for a time horizon of 30 years show that components such as food wastes and rubber together with leather and wood can be characterized by a low and relatively constant annual growth (approximately 1 to 1.5 percent and approximately 3.5 percent, respectively), whereas the annual growth rate of other categories such as plastic, metal and glass is predicted to vary considerably. Such results are of great importance if we realize, for instance, that the capacity demand for an incinerator not only increases with total weight, but also with increases in heating value (Btu/lb); Niessen and Chansky predict that a unit designed for a peak of 250 tons/day (227 kkg/day) of 1968 refuse may be confined to a useable capacity of only 215 tons/day (195 kkg/day) by 2000. The predicted growth of 25 percent of the paper component would also have the disadvantage for conventional collection, storage and handling operations insofar that the bulk density would decrease. In terms of a refuse grinding system, the rapid growth of a component that can be ground justifies the implementation of such a system. The projected slight drop in the metal content of refuse (an ungrindable category) is a further positive point for the wet transport system. The glass fraction as a portion of the daily refuse could greatly decrease if low cost beverage and good grade plastic containers are developed or if the one-way glass bottle concept is abolished. Indeed, preliminary results from Oregon, where the "Minimum Deposit Act" was signed into law in June 1971 and went into effect on October 1, 1972, seem to indicate that the law has had its intended effect.[22] The possible major increase of plastic (approximately 40 percent in New York according to Niessen and Chansky) will be a major setback for almost all conventional transport processing and disposal systems, but perhaps would have relatively little impact on a wet system.

These general results can only be extrapolated to local situations in conjunction with local population growth and local differences of solid waste characteristics and generation rate. Moreover, the basic data of Niessen and Chansky include residential and commercial solid waste whereas our interest is confined to the residential solid waste.

Regionalization of processing and disposal management is mentioned in several of the reports addressing the future of Greater Springfield's solid waste management. In particular, the report of the Raytheon Service Company[23] on solid waste management in Massachusetts and the Maguire report,[24] which is oriented to a short term solution of the solid waste management difficulties in the Greater Springfield area, are pertinent to our analysis.

The Raytheon Report suggests a solution within a district of communities: Agawam, Chicopee, East Longmeadow, South Hadley, Springfield and Westfield. In 1970, the total population of this district is reported as 376,000 and the total generation of residential and commercial waste is estimated at 275,000 tons/year (249,425 kkg/yr). The figures for the year 2000 are estimated at 458,500 residents and 449,000 tons/year (407,243 kkg/yr), respectively. The size and composition of the district were established as functions of the geography and the transportation network, and a rough balance between urban and suburban populations was anticipated. An approximate population increase of 20 percent is assumed, occurring mainly in the suburban communities around the core of Springfield, Chicopee, and Holyoke. The cities' figures are supposed to stay relatively constant. Raytheon claims that the changing character (urban to suburban) accounts for the 64 percent increase in waste generation forecast for the year 2000. The average daily estimated waste rate of 1056 tons (amount handled in a 5-day work week, 260 days/year) will increase from 1056 tons to 1727. According to Raytheon's detailed figures, approximately 500 tons (454 kkg) will originate from Springfield.

Maguire's Report is concerned with a short-term solution of the situation in the Greater Springfield area up to 1978. A regional solution for processing and disposal is recommended with implementation according to Chapter 748 of the Acts of 1965 for the Commonwealth of Massachusetts (i.e., by means of voluntary rather than mandatory regionalization).

Springfield would be part of the Sub-District defined by the communities of Agawam, East Longmeadow, Longmeadow, Springfield and West Springfield. The recommended system for this Sub-District is:

1. A central sanitary landfill should be located near Bowles Airport in Agawam which will serve as the disposal site for the entire district. (The site has an industrial zoning classification.)
2. A shredder/transfer station facility should be utilized by each of the five communities and located at the present Springfield refuse disposal site on Bondi Island.

In addition, investigations should be continued into the utilization of prepared refuse to the existing oil fire boilers of the Western Massachusetts Electric Company located on land adjacent to the Springfield disposal site.

The resulting disposal costs are estimated at $4.76/ton ($5.25/kkg) including the ownership of the landfill site ($10,000/acre), the construction of the shredder facility, the transport of shredded material to the disposal site and the administrative costs. No provision for adjustments of the transport cost to the shredder are made, although some of the towns are penalized by increasing distance. The area of the proposed site is reported as 120 acres (48.6 ha). Application of the trench method with a depth of about 12 feet (3.66 m) for disposal would provide for filling of about 330,000 tons (299,310 kkg) if the in-place density of the solid waste is estimated at 800 lbs/cu yd (475.2 kg/cu m). Although the Maguire Report does not indicate any expectation on the site's life, the estimated capacity appears reasonable[25] to dispose of the roughly estimated total refuse up to 1978; the 1973 refuse of the district is assessed at 174,400 tons/yr (158,181 kkg/yr) and the 1978 refuse at 194,300 tons/yr (176,230 kkg/yr). Plot line estimation yields a cumulative total of 911,800 tons (827,003 kkg) up to 1978. An environmentally sound operation would make sure that the terminal use of the site should be similar to its original industrial classification.

Collection of Nongrindables

Seasonal Peaks. The substantial seasonal peaks, and especially the fall peak of garden wastes, will have an important impact on the final design of a wet systems implementation. If one assumes that the peaks are composed of largely grindable material, as would be the case for the fall peak, then the treatment plant would need to be able to handle load fluctuations much higher than otherwise necessary. Moreover, substantial quantities of freshwater would be necessary to augment the normally available grinding water supply, which in turn might impose significant demands on the water system. On the other hand, if the peaks are composed of largely nongrindable materials, as would be the case in spring, at which time relatively bulky attic wastes appear to be the major component, a regular schedule of nongrindable collection (based on a more or less constant generation rate of nongrindable residuals) would be substantially disrupted by strong peaks. Indeed, aperiodicity in nongrindable collection might follow unless additional storage space is available. Perhaps compactors might continue to play an important role here, as the operational complexities of aperiodic collection schedules are formidable.

Bulky Wastes. The problem of bulky wastes was also found to be much greater than originally anticipated, because one must expect that a significant fraction of the bulky wastes now collected by the regular collection could not be ground by virtue of its bulk (rather than by virtue of its composition). The majority of the bulky waste appears to be of such a size that it can be included in a normal container, or is picked up by the collection crews as a matter of habit (if not as a matter of regulation); and thus the existing bulky item collection is reserved primarily only for the exceptionally heavy or bulky material. But small furniture, large plastic toys, small appliances, and the like, would not be readily grindable, and thus the demand for bulky item collection would undoubtedly increase under a wet systems implementation. At the very minimum, a doubling of the bulky item collection might be expected.

Unfortunately, we have only our qualitative observations taken during the route surveys to support this contention, and quantitative data is needed before a more exact judgment can be made. We shall return to this point in our recommendations for further research.

Commercial Establishments: The city of Springfield seems to feel very strongly about providing solid waste collection service to commercial establishments, as evidenced by the city's willingness to pick up commercial refuse on residential routes without charge. It seems reasonable to assume therefore, that the city would also be willing to let such commercial establishments install grinders to the extent that the nature of their refuse would be compatible with sewer transport. Because the collection of nongrindables would be very infrequent, inclusion of commercial establishments in the latter collection would not replace the need for regular weekly collection of commercial refuse were grinding not allowed.

It would make no sense for the city to provide a special service to this group of customers, since the cost reduction in the conventional system would be compromised by collection from spatially disperse locations requiring substantial travel from pickup to pickup. In the downtown areas, however, where the spatial concentration of commercial establishments would continue to allow efficient collection, the existing Friday night service could well be continued, using the same vehicles as would collect nongrindables from residential areas during the day.

If commercial establishments were allowed to use refuse grinders, rigorous enforcement of ordinances specifying prohibited materials would be necessary. A permit granted only after analysis of a commercial establishment's refuse, with the permit fee applied to the cost of sampling and analysis of the refuse, might be one way of regulation. Because the new water quality legislation requires those who add industrial wastes to the sewerage system to pay an equitable portion of treatment costs, it is probable that commercial establishments would likewise need to pay some form of user charge. Grinders at most commercial establishments would obviously depend entirely on freshwater for grinding, and hence metering of the freshwater inflow to the grinder could be used for an equitable user charge since the quantity of water used will be proportional to the weight of refuse ground and introduced to the sewer.

Emergency Collection. An important consideration in assessing the acceptability of the wet systems concept is that of its flexibility to accomodate failures. The capital intensity of the wet system would appear at first glance to compare poorly with the existing system whose labor-intensity and the possibility of incentive and overtime schemes makes it relatively easy to handle unforeseen refuse peaks or equipment failures; witness for example, the existing arrangements in Springfield where crews who have finished early are assigned to other routes in cases of greakdown or exceptional peaks.

There are two sources of potential failure of the wet system. The first is that of grinder breakdown, and clearly an emergency collection, available on demand, would need to be available for such situations. However, some form of incentive would be necessary to expedite repair of the grinding equipment, and a nominal pickup fee imposed after one or two weeks of emergency collection might be appropriate.

The second, and potentially more serious problem, would follow a sewer blockage. If a sewer blockage did occur, some mechanism would be necessary to inform upstream residents to cease use of their grinders until repairs were complete, as the continued load of refuse solids to a situation of reduced flow velocities would clearly aggravate the problem.

These problems, coupled with the possibly aperiodic collection of nongrindables and the by appointment bulky item collection, would necessitate both an intensive public information campaign as well as a unified operations center for refuse collection and sewer maintenance.

Frequency and Cost of Collection. Using the relationships for the frequency and cost of collection on nongrindables as developed in the Phase I report,[26] it is estimated that between three and four regular collections would be needed per year (i.e., in addition to the by appointment bulky waste collection), and that the annual per household cost would fall from $17.50 to $2.50. Because of the lack of detailed data for each existing route, a more precise definition of the collection frequency is not yet possible, especially in view of the significant differences that are evident from route to route, but for which we have as yet only qualitative rather than quantitative evidence.

Because of the drastically reduced collection frequency, and especially in view of the possible aperiodicity resulting from seasonal peaks, it may be necessary to send some form of media reminder to householders a few days in advance of the nongrindables collection. Clearly, it would be unreasonable to expect a householder to remember the days of collection if spaced at such long intervals. Such notice might entail considerable administrative effort, and would probably presuppose a centralized and computerized system run in conjunction with the operational control of the vehicles.

REFERENCES

Chapter III

1. For example, with respect to bundled refuse, the ordinance states, "Yard rubbish and all old pieces of lumber, completely free of nails, shall be securely tied in bundles, the greatest dimension of which shall not be in excess of 3 feet and not exceeding 50 pounds. Solid bundles shall be stacked near the standard ash and rubbish containers on the regular collection day."

2. According to the Sewer Division's estimate, approximately 50 percent of all households in Springfield have garbage grinders.

3. For instance, a recent EPA study of the collection system of Fall River, Mass., concluded that (1) despite separate collection, garbage was present in much of the rubbish, and (2) separate garbage containers may present an odor and pest problem which would not exist if garbage were combined with refuse.

4. The Division of Solid Waste is also responsible for street cleaning, including the removal of dead animals from the streets. Presently, dead animals are buried, but an incinerator is planned for the future.

5. It should be also mentioned here that no hazardous waste is collected on route by municipal forces (Hazardous waste is all waste of a pathological, explosive, radioactive, or toxic nature).

6. See below, Chapter V.

7. The citizens' group consisted of a loosely knit organization made up of several coordinators who organized service and volunteer groups from Springfield into a recovery campaign (from personal communication with Mrs. Stanley Zucher who was instrumental in the group's activities.)

8. See also Chapter VI for further details on resource recovery.

9. As part of the mayor of Boston's austerity program, the Department of Public Works decided to cut down on the collection of refuse in the city beginning April 1, 1973. The proposed layoff caused the threat of a strike of Boston's sanitation workers. At the last moment, city officials reached a "compromise" settlement; the agreement consolidated separate rubbish and garbage collections into one pickup a week, but avoided layoffs of sanitation workers, who now undertake street-cleaning tasks. Instead of the expected $800,000 savings over the next 12 months, a savings of $500,000 was anticipated due to the compromise between city officials, private contractors, and union leaders.

10. The preferred truck is the Leach 2A that compacts up to 600 to 850 lbs/cu yd.

11. The Division of Solid Waste is still called "Ashes and Refuse" in the accounting office of the city.

12. Partridge, L.J. and J.J. Harrington, "Quantitative Estimates for Solid Waste Management in Boston," Environmental Systems Program, Harvard University, Discussion paper 71-4, December 1971.

13. Ralph Stone and Co., Inc., "A Study of Solid Waste Collection Systems Comparing One-Man with Multi-Man Crews," Public Health Service Publication No. 1892 (GPO, 1969), pg. 61, Table 8.7.

14. Clark, R.M., *et al.*, Cost of Residential Solid Waste Collection J.San.Eng.Div., ASCE, Vol. 97, No. SA5, pp. 563-568, October 1971.

15. See Phase I report, Chapter VI.

16. Private communication (August 29, 1973).

17. Wersan, S., J. Quon and A. Charnes, "Mathematical Modeling and Computer Simulation for Designing Municipal Refuse Collection and Haul Services," *EPA - Research Grant UI-00699*, 1971.

18. Quon, J.E., R.R. Martens, and M. Tanaka, "Efficiency of Refuse Collection Crews," *J.San.Eng.Div.*, ASCE, Vol. 96, No. SA2, April 1970.

19. Clark, R.N., J.M. Sweeten and D.G. Greathouse, "Basic Data for Solid Waste Pilot Study," *J.San.Eng.Div.*, ASCE, Vol. 98, No. SA6, December 1972; and R.N. Clark, "Measures of Efficiency in Solid Waste Collection," *J.Env.Eng.Div.*, ASCE, Vol. 99, No. EE4, August 1973.

20. Meier, P., J. Kühner, and J. Martell, "A Preliminary Assessment of Wet Systems for Residential Refuse Collection," Report by Curran Associates, Inc. to EPA Solid Waste Research Laboratory, Cincinnati, Ohio, March 1974.

21. Niessen, P. and J. Chansky, "The Nature of Solid Waste," ASME, Incinerator Division, 1969.

22. Claussen, E., "Oregon's Bottle Bill: The First Six Months," *EPA publication, SW-109*, 1973.

23. Raytheon Service Company, "Solid Waste Management Study Report," May 1972.

24. Maguire, C.E., "Recommended Short Term Program for Solid Waste Management in the Greater Springfield Area," 1973.

25. This is particularly true since 800 lbs/cu yd is a very conservative estimate for the filled in density of shredded material.

26. Meier, *et al.*, *op. cit.*, Chapter VI.

CHAPTER IV

HYDRAULIC TRANSPORT

The Springfield Sewerage System

A report for the Lower Pioneer Valley Regional Planning Commission[1] estimates that 93 percent of the population in Springfield, Massachusetts, is provided with sewerage service. Of the 610 miles (981 km) of sewer in the city, approximately 40 percent are sanitary sewers, 32 percent are combined sewers and the remaining 28 percent are storm sewers. The areas served by the combined sewer system are located in the older areas of the city, adjacent to the Connecticut River and the Indian Orchard area. Since the sewage treatment plant is located across the Connecticut, opposite the areas served by combined sewers, even sewage emanating from the separated areas often discharges into a combined sewer before reaching the treatment plant. Figure 14 shows the areas of combined and separate sewers as well as the locations of the treatment plant, pumping stations, lift stations and the main interceptors.

Combined Sewer Overflows. The combined sewers in the city have been designed to carry dry weather flows and a portion of the stormwater runoff (up to 55 mgd or 20,625 cu.m/day). The interceptors have specific overflow points to release excess flows when the combined flow approaches 3 to 5 times the average dry weather flow. A report by Camp, Dresser and McKee[2] estimates that a 30-minute duration, 2-month frequency rainfall results in a discharge of 19,500 lbs (8853 Kg) of Biochemical Oxygen Demand (BOD_5) into the Class C waters of the Connecticut River. This waste load is enough to depress the Dissolved Oxygen (DO) content of the Connecticut River at dry weather flow conditions by 0.3 to 0.5 mg/l, which is significant in light of the present trend of upgrading stream quality.

Depositing ground refuse in these combined sewers will undoubtedly increase the overflow BOD_5 load and further depress the DO content. Therefore, it appears that sanitary flow will have to be separated from stormwater flow before ground refuse is allowed in the sewerage system. However, the need for separating combined flow is already justified on the basis of present damage to stream water quality. Consequently, the cost of separating combined sewers should not be assigned to the cost of a wet systems implementation.

Condition of Sewers. As reported by many investigators, the condition of the sewer pipe is an important factor in the determination of hydraulic characteristics. Factors such as misaligned pipe joints, roots, sticks in manholes, old sewers and rats are actually encountered conditions which must be considered in an evaluation of the feasibility of refuse transport. Optimistically, these conditions would not cause any more problems than they already do with normal sewage; but pessimistically, these conditions may cause a more rapid blockage of sewer lines,

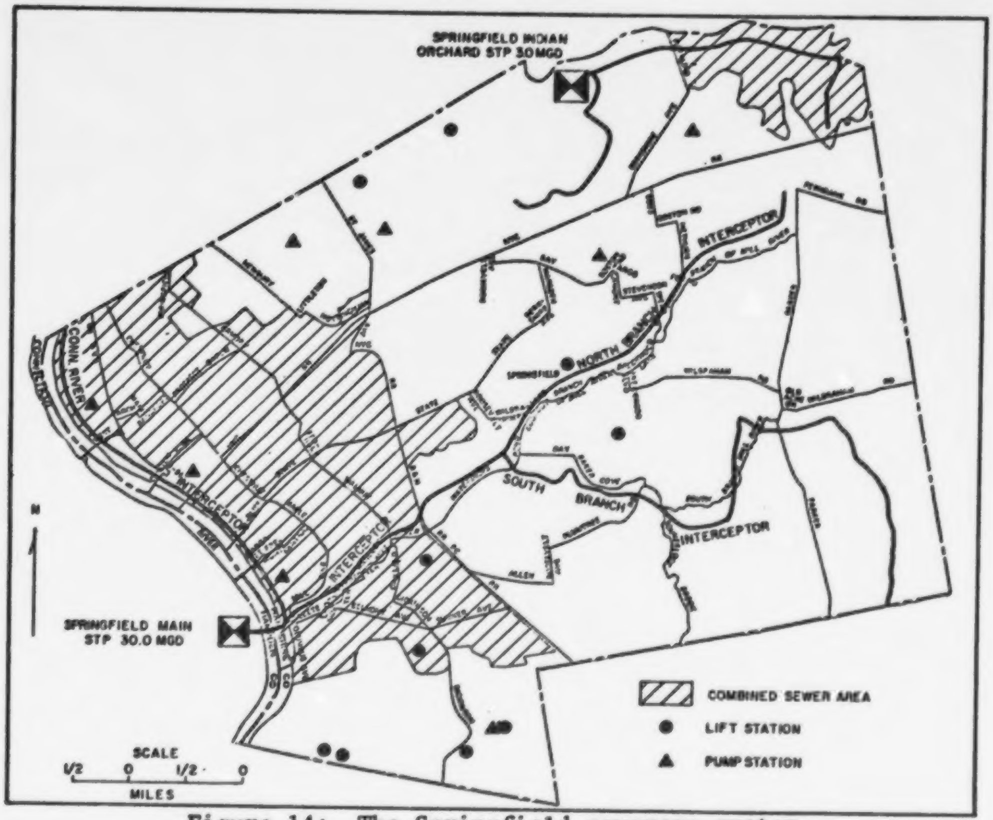
SPRINGFIELD INDIAN ORCHARD STP 3.0 MGD
INTERCEPTOR
NORTH BRANCH
CONN RIVER
SOUTH BRANCH
INTERCEPTOR
INTERCEPTOR
INTERCEPTOR
N
SPRINGFIELD MAIN STP 30.0 MGD
COMBINED SEWER AREA
LIFT STATION
PUMP STATION
SCALE
1/2 0 1/2 0
MILES

Figure 14: The Springfield sewerage system

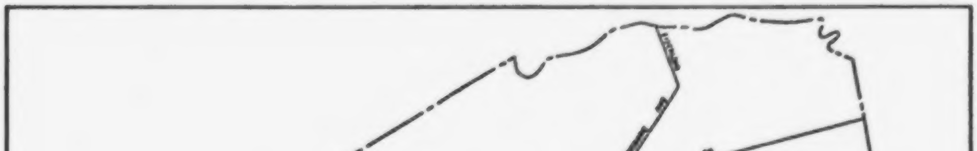
ROOTS
RATS
RATS
N
SCALE
1/2 0 1/2 1
MILE

Figure 15: Problem areas

an increase in the need for flushing and cleaning, and a proliferation of the rat population. Any of these events would result in an increased sewer maintenance cost directly attributable to the sewer transport of ground refuse.

Figure 15 indicates the areas of Springfield prone to some of the aforementioned problem conditions. Misaligned joints are difficult to locate and are assumed to exist to some extent throughout the city. Many brick sewers built before the turn of the century are deteriorating and are gradually being replaced. Sticks and stones dropped into manholes by children cause a significant portion of the sewer line blockages according to officials of the Springfield Department of Streets and Engineering. Three of the thirteen manholes investigated during the sewer survey (see below) were found to contain sticks.

Present Cost of Sewer Maintenance. The cost of maintaining Springfield's sewerage system is shown in Table 17. The largest item on the budget is cleaning of the main interceptor, involving the removal of sand and grease deposits each year during the winter months. Of the total city maintenance budget, the cost of cleaning and repairing sewers amounts to approximately 20 percent.

The city does not have a periodic sewer flushing program. It was discontinued a few years ago due to a shortage in manpower. Instead, city sewer maintenance crews are organized to quickly respond to emergency calls concerning blocked sewers. After the sewer line is unblocked and the emergency situation temporarily relieved, a crew follows up the emergency action by a thorough cleaning and flushing of the affected line. It is also interesting to note that flushing stations located at the end of many street sewers in the older central areas of the city were disconnected due to fears of a cross connection occurring that could possibly contaminate the water supply.

Future Plans. A report by Camp, Dresser and McKee[3] for the city of Springfield recommends a number of near and long-term improvements in the city's sewerage system. The first recommendation is to improve regulators and overflow devices along the Connecticut River. Presently, the majority of mechanical regulating devices are inoperable or the mechanical equipment has been removed. Improvement in the operation of these facilities will effectively reduce combined sewer overflow problems. The estimated cost of this improvement is $1,560,000.

The city of Springfield is also actively engaged in a combined sewer separation program, especially in areas of reconstruction and urban renewal. Areas scheduled for separation in the near future (see Figure 16) are:

1. The Brightwood area in the northwestern corner of the city bordering the Connecticut River (Area A).

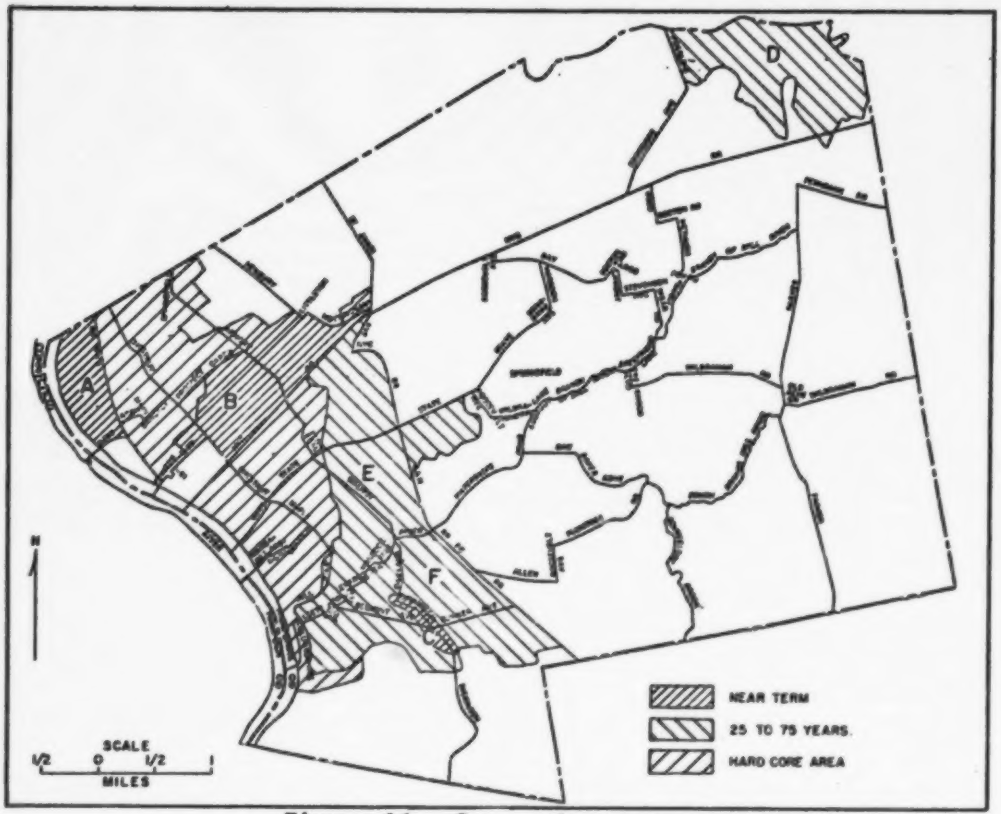
D
A
B
E
F
C
N
SCALE
1/2
0
1/2
1
MILES
NEAR TERM
25 TO 75 YEARS.
HARD CORE AREA

Figure 16: Separation program

Table 17: Sewer maintenance cost

ITEM	1970	1971	1972
Reconstruction of Sewer Mains	$ 3,644.25	$ 4,414.00	$ 17.75
Manhole Construction	7,945.67	14,158.47	6,511.74
Small Repairs	43,522.91	36,802.82	27,111.04
Flushing and Emergency Calls	6,420.89	6,399.07	10,203.82
Cleaning Sewer Main	43,390.52	49,284.46	46,592.09
TOTAL	$104,924.24	$111,058.82	$90,436.42

2. An area comprising 580 acres (234 ha) adjacent to U.S. Route 291 (Area B).

3. A 10-acre (4 ha) area located immediately adjacent to Dickinson Street (Area C).

It is interesting to note the general approach used in separating combined sewers in already established residential areas. Normally, if the existing combined sewer is still in good condition, it will be selected to become the sanitary sewer. This is understandable since costs can be reduced by not having to reconnect building connections and excavate to the depths required of sanitary sewers. What effect this policy would have on the transportability of refuse through these sewers is debatable. On the one hand, the small quantity of sanitary flows alone through the large diameter combined sewers may cause deposition of heavier solids. On the other hand, combined sewers are usually laid at a steeper slope than sanitary sewers (3 ft/sec minimum velocity) in order to transport sand and grit. Whether former combined sewers actually possess sufficient scouring velocities is discussed later in this chapter.

The report by Camp, Dresser and McKee also points out areas in the city where long range separation programs (say 25 to 75 years) appear feasible. These areas are (see Figure 16):

1. The Indian Orchard area where approximately 445 acres (180 ha) are served by combined sewers (Area D).

2. The western section of the city bounded by the B & M railroad tracks and the Mill River. This area contains approximately 1,008 acres (408 ha) (Area E).

3. The southwestern part of the city bounded by the Mill River to the north and a line almost to the East Longmeadow-Springfield line (Area F). Separation is already planned in part of this 836-acre (339 ha) area (Area C).

The estimated cost of separating the sanitary and stormwater flows for the three areas mentioned above are $10.2 M, $23.2 M, and $19.2 M, respectively. These cost estimates are based on a unit cost of $23,000 per acre and include the cost of constructing a new sanitary sewer system, disconnecting the sanitary house connection from the existing combined sewer and reconnecting to the new sanitary sewer system. However, as mentioned previously, experience in Springfield has shown that in most cases these costs can be reduced by constructing a new storm sewer instead of a sanitary sewer and using the former combined sewer to transport sanitary flows.

The remaining combined sewer area in Springfield is classified as a "hard core" area (see Figure 16). This area contains more than 1,990 acres (806 ha) and is for the most part highly commercialized and congested. Camp, Dresser and McKee estimates that the cost of separation in this area would probably range from $30,000 per acre in the northerly and southerly ends to $100,000 or more per acre in the central portion. Treatment of the combined wastewater and/or stormwater runoff would be less expensive at $6,550 to $8,500 per acre. However, even this cost is high compared to the estimated cost of treatment at the new Bondi Island treatment facility.

Due to the high cost of either separating or treating combined wastewater and/or stormwater runoff, the Camp, Dresser and McKee report recommends that neither of these approaches be adopted unless classification of the Connecticut River is upgraded. They observe that with rapidly advancing technology in wastewater treatment, a more efficient, less expensive treatment process may be available at that time.

Capability of the Springfield Sewerage System to Transport Ground Refuse

In the absence of actual experience or even pilot scale test results, it is difficult to establish a basis for a meaningful technical evaluation of a sewerage system's ability to transport ground refuse. However, recent trends in wastewater collection practices and the fundamental requirements of ground refuse transport, as determined by Foster-Miller Associates,[4] provide some insight into the conditions that ought to exist prior to allowing ground refuse in sewers.

The first condition is the separation of all combined flows, or at least the treatment of overflows, prior to discharge into the receiving stream. This condition is seen to be necessary before large scale deployment of refuse grinders is approved. Not complying with this condition would significantly increase the pollutional load to the receiving stream and thus run counter to present and future efforts at improving receiving water quality.

The second condition that must be satisfied to allow hydraulic transport of refuse is a minimum scour velocity of 2.5 ft/sec (0.76 m/sec). This condition was established by the laboratory experiments conducted by Foster-Miller Associates.[5] Not satisfying this condition, at least on a daily basis, would result in deposition and accumulation of the heavier components of a solid waste (glass, ceramics and aluminum) on the invert of the sewer pipe.

The thire requirement to be met is that sufficient water must be available to dilute the refuse to a hydraulicly transportable concentration. Foster-Miller Associates has concluded that a 1 percent concentration in smooth pipes and a .8 percent concentration in rough pipes would produce flow characteristics similar to that of water alone. Not complying with this requirement would cause non-Newtonian flow characteristics to prevail. Probable consequences of non-Newtonian flow include increased residence time in sewers promoting septic conditions and more frequent blockages, and, where the condition is not met at full flow, unallowable reduction in hydraulic capacity. We shall return to these problems later in this chapter.

Following is a brief analysis of the Springfield sewerage system's capability of meeting the three aforementioned conditions. Since design criteria and usage patterns are generally similar throughout the country, the analysis should be valid for many of the nation's urban areas.

Impact of Combined Sewers. As pointed out in a previous section, approximately 32 percent of the Springfield sewerage system is combined. Also, many of the sanitary sewers flow into older combined sewers. Allowing substantial quantities of ground refuse to be deposited in these sewers without treatment would further degrade the water quality of the Connecticut River.

Although large quantities of ground refuse in combined sewers would likely not be allowed, a small quantity of refuse deposited in sewers as a result of a limited deployment of the grinders may be acceptable. If grinder installation follows the rather gradual deployment pattern of garbage grinders (where in most cases only new homes are required to have grinders) the resulting yearly increase in BOD load would be small. Therefore, complete separation of combined sewers prior to allowing refuse grinders might not be necessary. The main impact of allowing refuse grinders on this scale would likely be a more rapid implementation of the already planned and scheduled sewer separation program. On the other hand, if a large scale deployment of the grinders over a short time period is deemed necessary to take advantage of the inherent economies of refuse grinding, then large capital sums would be needed to finance an accelerated combined sewer separation program.

The potential use of neighborhood refuse grinders in the city of Springfield presents a special problem since those sections in the city amenable to this type of system are all located in combined sewered areas. Figure 17 shows how those areas justifying neighborhood grinders overlap the combined sewered sections. Consequently, it may be necessary to halve the use of these grinders during overflow periods. A likely consequence of this restriction is the requirement that sufficiently large storage facilities be made available to accommodate collected refuse during rainy periods.

Scour Velocity Investigation. The laboratory studies conducted by Foster-Miller Associates has determined that for the particle size range emanating from the grinder, a minimum velocity of 2.5 ft/sec (0.76 m/sec) is needed to maintain self-cleansing conditions in sewers. Since steel cans have already been eliminated due to excessive power requirements for grinding, high grinding costs and problems in appurtenances, especially siphons, this velocity is required to transport the glass, ceramic, and aluminum components only. No determination was made as to how often or how long this scouring velocity should be present. However,

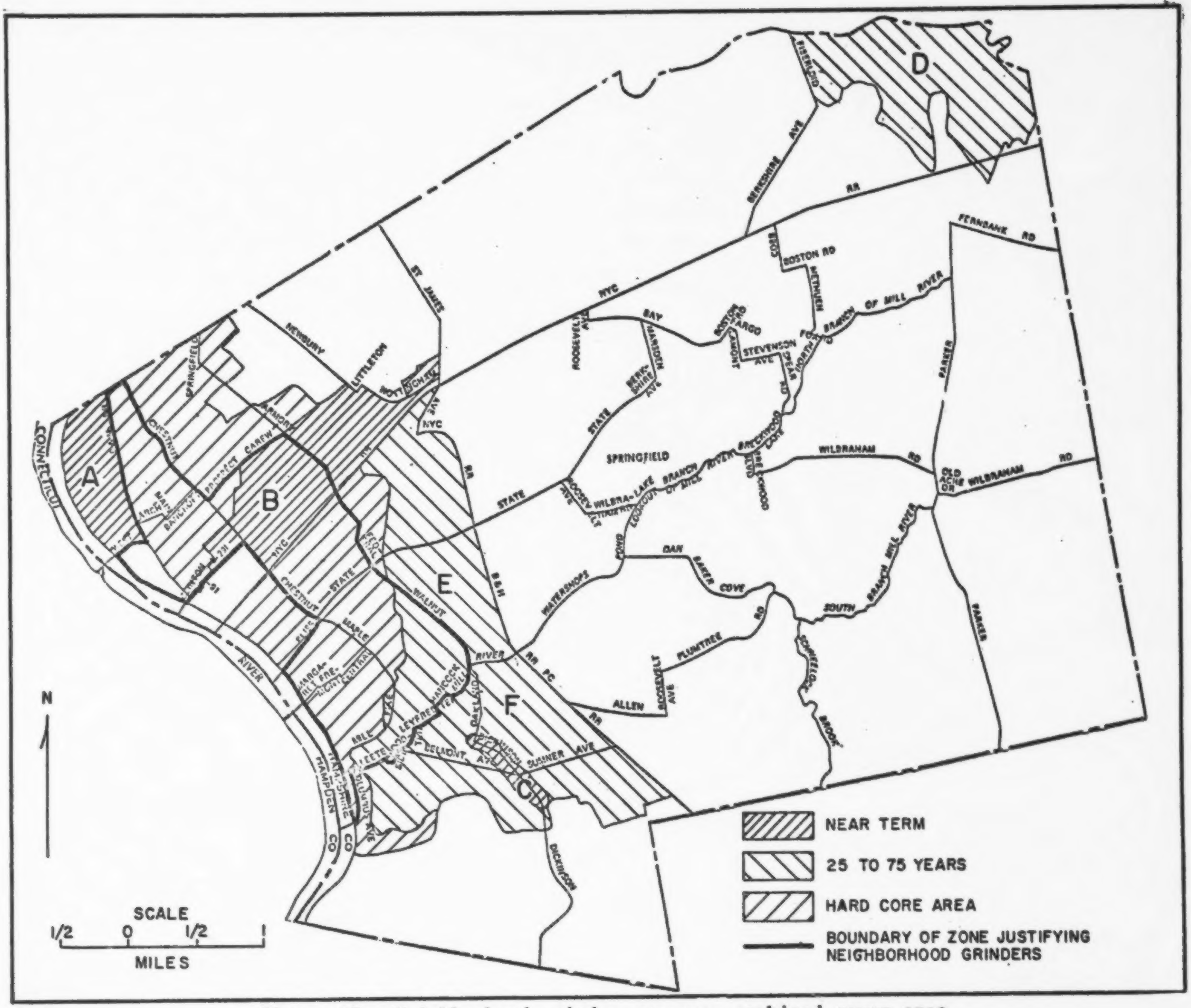
A
B
C
D
E
F
SPRINGFIELD
CONNECTICUT
RIVER
HAMPSHIRE CO
HAMPDEN CO
N
SCALE
1/2 0 1/2 1
MILES
NEAR TERM
25 TO 75 YEARS
HARD CORE AREA
BOUNDARY OF ZONE JUSTIFYING NEIGHBORHOOD GRINDERS
STATE
WILBRAHAM RD
PARKER
BOSTON RD
NYC
RR
B&M
ALLEN
PLUMTREE
DICKINSON
SUMNER AVE
WALNUT
CHESTNUT
MAPLE
BERKSHIRE AVE
FERNBANK RD
ST JAMES
NEWBURY
LITTLETON
WATERSHOPS
SOUTH BRANCH MILL RIVER
DAN BAKER COVE
BRECKWOOD BLVD

Figure 17: Neighborhood grinder area vs. combined sewer area

in order to avoid excessive accumulation of debris, it would not be unreasonable to require daily scouring of settled materials. Otherwise, deposited materials may combine with grease or other cohesive materials to form a cake resulting in a further loss in hydraulic properties.

Assuming unobstructed flow conditions, there are two occasions where sewers are incapable of providing the required 2.5 ft/sec (0.76 m/sec) scour velocity. The first occasion is where sewers are designed according to the minimum requirements of most health departments which specify a "minimum full-conduit velocity of 2 fps."[6] Since maximum flow velocities are achieved at full or near full flows, these sewers cannot be expected to flow faster than 2.0 ft/sec (0.61 m/sec). The second occasion is where sewers are not flowing full enough to attain a 2.5 ft/sec (0.76 m/sec). Both of these situations will be discussed in more detail in the following sections.

Sewers Laid at Minimum Slope. The likely locations of sewers laid at minimum slope, defined as sewers with a maximum full conduit velocity of 2.0 ft/sec (0.61 m/sec), are in the flatter sections of town where steeper slopes would have resulted in higher excavation costs during construction. Once these sections are located, it becomes a simple matter to identify which streets are likely to contain minimum sloped sewers. This procedure was used in Springfield and the streets in question were checked against actual sewer construction drawings. This investigation revealed that some sewers are indeed laid at minimum and even below minimum slope. Table 18 lists some of the streets found to have minimum sloped sewers. A Manning coefficient (n) of 0.014 was used in determining minimum slope values.

The impact of sewers laid at less than minimum slope is that even when flowing full or near full, the scour velocity is never reached. Consequently, if refuse grinders were allowed in homes connected to these sewers, glass and other high specific gravity materials would certainly settle out.

Table 18: Some streets having minimum slope in Springfield

Street	Diameter(in) (x2.54=cm)	Length (ft) (x0.305=m)	Slope (ft/ft)
Acrebrook Road	10	1,340	.0029[a]
Durid Hill Road	10	606	.0029
Parker Street	10	1,413	.0029
Gourley Road	10	752	.0029
Nagle Street	10	1,350	.0030
Peerskill Avenue	10	700	.0030
Lumae Street	10	2,082	.0025[b]
Donbray Road	10	1,204	.0030
Ferncliff Avenue	10	607	.0020[b]
Melba Street	10	433	.0030

[a] Minimum slope for 10" pipe, n=0.014 and V=2.0 ft/sec is 0.0029 ft/ft.

[b] Below minimum slope.

The quantity of material that would accumulate in these sewers can easily be determined. For example, if we assumed a refuse generation rate of 2.25 pounds per capita per day (1.02 kg/cap/day), a 10 percent glass and ceramics concentration with a bulk density of 91 pounds per cubic foot, the volume of glass generated per year per person is 0.9 cubic feet. If all 36 single family homes on Acrebrook Road (see Table 18) possessed a refuse grinder with glass allowed as a grindable item, the volume of glass deposited in the street sewer line each year would be approximately 118 cubic feet (3.3 cu m) based on 3.63 persons per household as given by the 1970 census. This amount is sufficient to cover the invert of the 10-inch (25 cm) diameter sewer line with approximately 2.2 inches (5.6 cm) of glass and ceramic material. At this rate, the lateral would be half-filled with refuse in 3.0 years. In fact, however, accumulations will tend to concentrate near manholes rather than be evenly distributed, and hence the actual result would be even more drastic.

Sewers Laid at Greater Than Minimum Slope. Because of the hilly or rolling terrain found in most parts of the city, a great majority of the sewer lines are laid at slopes greater than minimum. Nevertheless, the flow velocities in these sewers may still be less than 2.5 ft/sec (0.76 m/sec) if the quantity or depth of flow is insufficient. The relationship between relative flow depth (d/D) and relative velocity (V/V_f) is shown in Figure 18. For example, if a sewer is designed to flow at 2.5 ft/sec (0.76 m/sec) when full, at .3 full the velocity would only be 1.50 ft/sec (0.46 m/sec). Prolonged periods of time with flows at this depth would, again, result in a serious deposition problem. In order to determine the maximum daily velocities reached in typical sewers in the city of Springfield, a six-day survey was conducted on seven street sewer lines. The streets chosen for the survey were:

> *Malden and Bloomfield* - these streets are located in an older duplex area. Both sewers are combined and may serve as future sanitary sewers.
>
> *Denver, Aldrew and Fenway* - are streets located in single family home areas. They have a full pipe velocity above 2 ft/sec (0.61 m/sec).
>
> *White Oak and Acrebrook* - these streets are also located in single family home areas. They have a full pipe velocity of 2 ft/sec (0.61 m/sec).

There were a number of reasons for selecting these particular sewers for the survey. Firstly, it was decided that a representative cross section of typical residential areas sewers should include both new and old sewers, combined and separated sewers, and sewers with a full pipe velocity at and above the minimum scouring velocity. In order to obtain accurate depth of flow readings, it was also necessary to select manholes with a single inlet and outlet and with no changes in slope. For

Table 19: Sewer survey

Street	Year Built	Kind of Pipe	Kind of Sewer	Diam. (in)	Slope s	Total Length of Connected Pipe Upstream of Manhole (ft)	# of Housing Units Connected Upstream of Manhole	Q_f cfs	V_f ft/sec
Malden	1899	VC	Combined	12	.0050	784	64	2.4	3.00
Bloomfield	1914	VC	Combined	18	.0050	1,789	77	6.9	3.80
Denver	1926	VC	Sanitary	10	.0030	2,614	67	1.1	2.05
Aldrew	1958	VC	Sanitary	10	.0055	920	26	1.5	2.70
Fenway	1958	VC	Sanitary	10	.0045	823	20	1.4	2.50
White Oak	1964	AC	Sanitary	10	.0029	3,404	42	1.1	2.00
Acrebrook	1964	AC	Sanitary	10	.0029	1,340	36	1.1	2.00

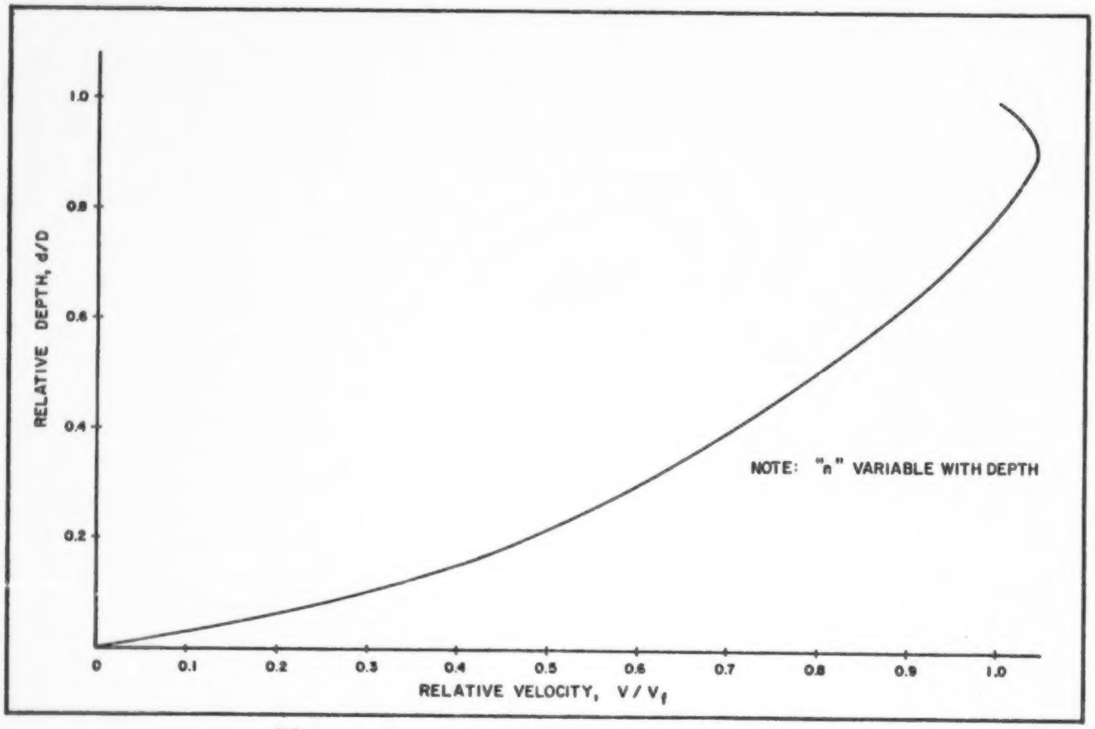

Figure 18: Velocity vs. depth of flow

safety reasons, manholes were chosen away from heavy traffic; usually one manhole upstream from the intersecting manhole between the street sewer and the interceptor. As evidenced by the aforementioned selection process, the choice of sewer lines was not strictly random. However, it is our opinion that they are representative of typical street sewers likely to be found in any large city in the country.

It should also be pointed out that the sewer survey did not include any trunk sewers or large interceptors. Instead, the survey was confined to street sewers only, which comprise 70 to 80 percent of the total sewerage network. It is this portion of the sewer system that is most sensitive to the problems of hydraulic transport.

The method used to record the maximum daily depth of flow at each manhole involved marking the inside of the pipe with blue carpenters chalk or a water soluble paint. As the water level rose inside the pipe, it would wash away the chalk or paint and thus leave a mark. Although one could not tell the duration of maximum flow from this information, one might assume that it would be sufficient to scour those deposits influenced by the velocity achieved at a particular depth of flow.

The survey data obtained for each sewer line, and the calculated maximum daily scouring velocities, are shown in Appendix A. The survey began on the 14th of August and terminated on the 20th of August 1973. During this time period, the city of Springfield recorded 0.02 and 0.03 inches (.05 and .076 cm) of precipitation on the 15th and 16th of August, respectively. City maintenance records for each sewer line were also reviewed and the information recorded on the survey data sheets.

Knowing the maximum depth of flow as a result of the sewer survey and the full pipe flow rate and velocity (from Table 19) it was possible to determine the maximum velocity reached during that particular day (V max) using the design manual curve (Figure 18). The results indicate that in not a single case, even in sewers with slopes above the minimum, did the actual sewer velocity ever reach 2.5 ft/sec (0.76 m/sec). Out of 40 observations, the highest maximum velocity reached during the survey period was only 1.62 ft/sec (0.5 m/sec) and the lowest maximum velocity was 0.74 ft/sec (.225 m/sec).

In addition to the standard sewer design curves (Figure 18), Foster-Miller[7] developed design charts based on their experimental results. Figure 19 is one of these design charts and shows the relationship of relative flow depth (d/D) to relative flow velocities (V/V_{fo}) for various refuse concentrations. This chart was used to determine the maximum velocity values shown in Appendix A for 0, 0.5 and 1.0 percent refuse concentrations. As in the first case, none of the sewers ever attained 2.5 ft/sec (0.76 m/sec) scour velocity. Also note that the maximum daily velocities (V max) are less for concentrations of 0.5 percent and 1.0 percent than for water alone.[8] This indicates that the limiting concentration of refuse needed to maintain flow characteristics similar

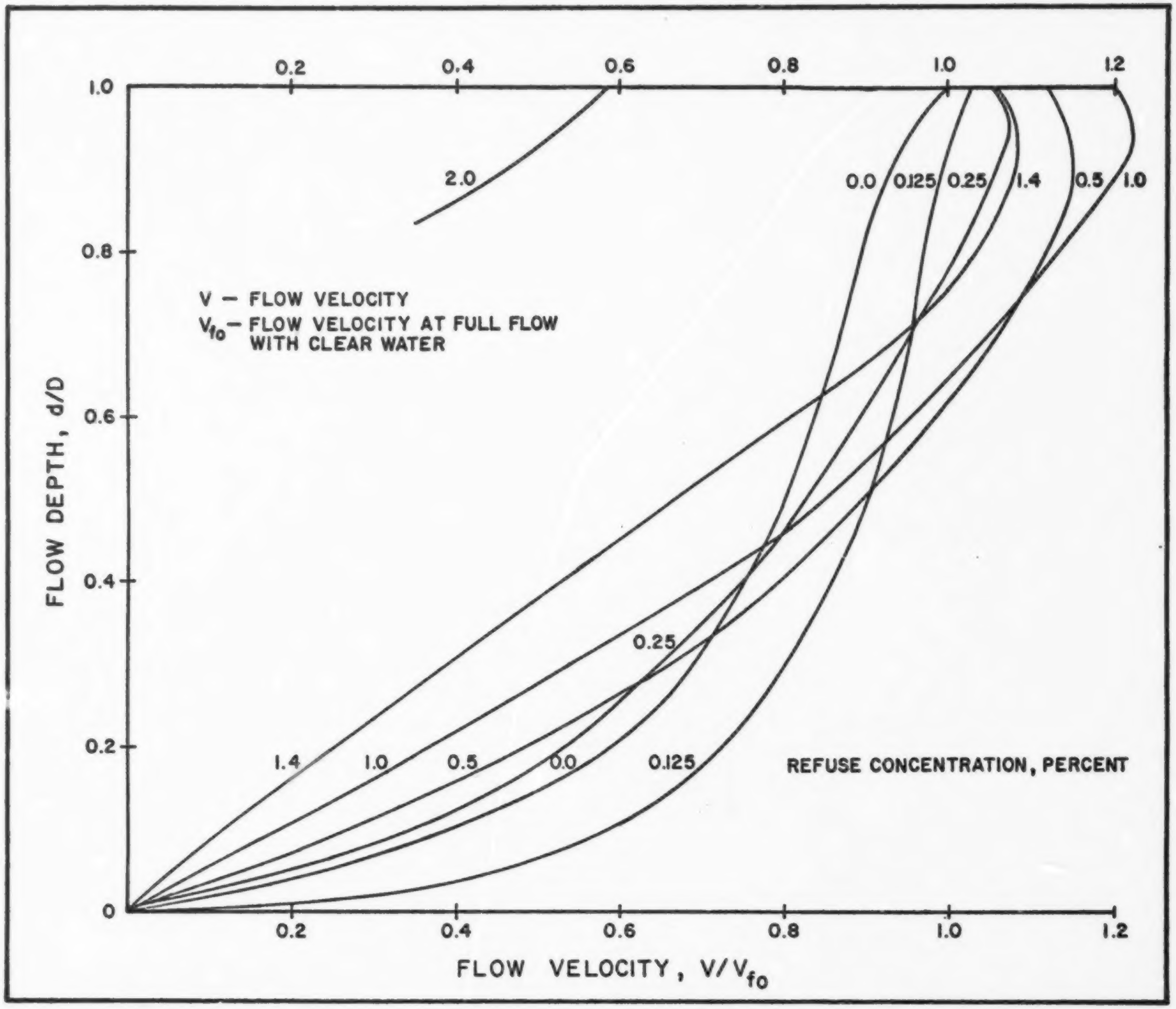

Figure 19: Design chart for flow velocity for the flow of ground refuse in smooth sewer pipes

to that of water is actually less than 1.0 or even .5 percent. Examination of Figure 19 reveals that the actual limiting refuse concentration for sewers flowing at the depths observed (.1 to .3 d/D) is as low as 0.25 percent.

Conclusions. The scour velocity investigation of the Springfield sewerage system revealed that sewers laid at minimum slope (to produce a full pipe velocity of only 2.0 ft/sec) are not uncommon. It also revealed, through a sewer survey, that even in sewers where the design slope is great enough to produce velocities in excess of 2.5 ft/sec (0.76 m/sec), the quantity or depth of flow is insufficient. Consequently, glass and other high specific gravity materials would accumulate on the bottom of the pipe. The sewer survey also revealed that the limiting concentration of refuse may be lower than the 1.0 percent value originally claimed. This is again due to the shallow depths of flow actually occurring in typical street sewers. The impact of both of these discoveries on the feasibility of hydraulic transport of ground refuse in sewers is discussed in the following sections.

Alternative Solutions to the Scouring Velocity Problem

The scour velocity investigation previously discussed presented evidence that sewers laid at less than minimum slope (to produce a full pipe velocity of 2.0 ft/sec) do exist and that these sewers as well as sewers laid at greater than minimum slope do not flow full enough to attain the required 2.5 ft/sec (0.76 m/sec) scouring velocity. One alternative to resolve this problem would be the elimination of glass, ceramic, and aluminum material from the list of grindables, along with steel cans, heavy gauge plastic and heavy gauge aluminum. However, this would increase the collection cost of nongrindables and would seriously reduce the convenience to the user.

Preventative Maintenance. Instead of prohibiting the grinding of glass and other high specific gravity materials, it may be feasible to flush it from the affected sewer lines. The frequency of flushing would depend on the rate of accumulation and the effect of the accumulated deposits on the hydraulic properties of the pipe. Without actual experience or field test results, one can only assume a likely frequency. Based on previous calculations which indicate an accumulation of 2.2 inches of glass in one year, an intensive flushing program would probably be required.

The cost of cleaning the affected sewers will largely depend on the type of equipment required. For example, if the deposited material forms a cake and adheres to the sides of the pipe, or if there are large quantities of material, a bucket machine may be needed. Bucket machines consist of two powered winches connected by a steel cable; one of the winches pulls the bucket into the line until the operator feels it is loaded with debris. The other winch pulls the bucket out and dumps the debris into a trench. Three or four men are needed to operate this equipment, and they can clean between 500 to 1000 feet (153 to 305 m) per day.[9] The total unit cost of using the method to clean sewers can range from 50 to 60 cents per foot.[10] Municipally operated equipment may cost slightly less.

If the deposited material behaves much like the sand and grit found in many sewers today, then a water jet may be used. The water jet system uses a probe equipped with a back-spraying nozzle which directs a high velocity stream against the walls of the pipe (see Figure 20). It flushes light materials down the pipe and deposits heavier material in the manhole where a vacuum unit lifts it into a transportable container. A number of attachments give the water jet root and solids penetrating capability. Simultaneous vacuuming lowers backpressure that might occur as a result of solids redepositing and build-up behind the water jet. Manufacturers of such equipment advertise the need for only one operator; however, 2 or possibly 3 men may actually be required.[11] The water jet is capable of cleaning 2000 ft/day[12] (610 m) at a total cost of 20 to 30 cents per foot.[13] Again, these costs should be slightly less for municipally operated systems. Besides being more efficient and less costly, this method is also less hazardous. The operator is protected from traffic by the entire vehicle and there is less need to climb into and out of manholes. There are other sewer cleaning devices such as sewer rods and sewer balls. However, these devices are not as convenient for removing deposited materials from the bottom of the pipe.

If ground refuse is allowed in sewers, it is likely that both types of cleaning equipment (bucket machine and water jet) will be needed. The bucket machine will be needed to clean sewer lines known to contain large quantities of debris. The water jet is most effective in cleaning sewers with minor deposits, as might be expected in a preventive maintenance program. The city of South Bend, Indiana, plans to use both types to maintain a three-year cycle preventive program.[14]

Springfield already has a bucket machine and is in the process of purchasing two water jets at approximately $16,000 each.[15] This is the cost of the water jet alone. A vacuum unit would cost an additional $16,000. Each water jet is capable of cleaning 75 miles (121 km) of sewer per year. If 75 percent of the 440 miles of sanitary sewer require cleaning each year as a result of grinding refuse, then five water jets would be required at a total capital investment of $160,000 (including the cost of a vacuum unit with each water jet). Assuming that an annual flushing with the water jet would be sufficient to maintain good hydraulic properties, the total annual cost would range from $348,480 to $522,720 (based on 20 to 30 cents/foot). This is approximately 3 to 5 times greater than the present annual budget. On a per household basis, the costs would range from $6 to $9 per year. If extensive use of the bucket machine were needed, the cost per foot would triple (50 to 60 cents/foot vs. 20 to 30 cents/foot). Therefore, it is recommended that the water jet be used where possible, even if biannual flushings are needed. Again, it should be emphasized that the real

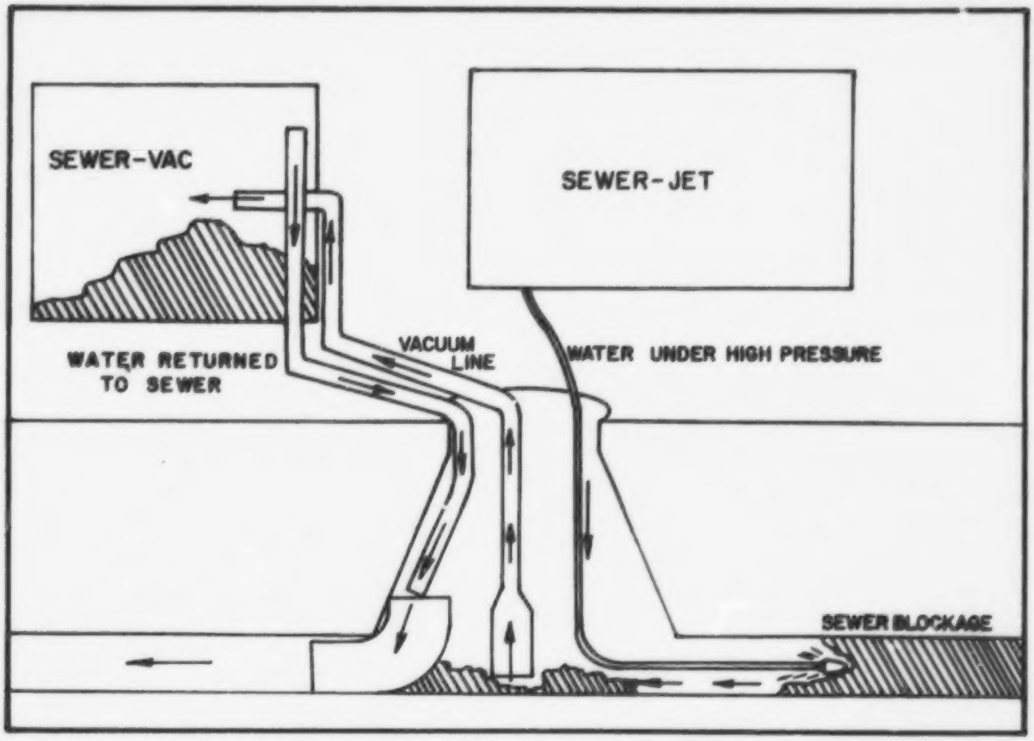
SEWER-VAC
SEWER-JET
VACUUM LINE
WATER RETURNED TO SEWER
WATER UNDER HIGH PRESSURE
SEWER BLOCKAGE

Figure 20: Schematic of sewer jet cleaning method

costs will not be known until the actual frequency of flushing required is determined.

Redesign of Gravity Sewers. Another alternative to eliminating glass as a grindable item is to redesign the sewer system to achieve the minimum scour velocity of 2.5 ft/sec (0.76 m/sec) at the shallower depths common in sewer flows. This would mean steeper sloped sewers and a more frequent use of lift stations. This might be considered feasible for newly developing and urban renewal areas that could readily implement new design standards.

By using the charts developed by Foster-Miller Associates, it is possible to design a sewer capable of achieving the minimum required scouring velocity of 2.5 ft/sec (0.76 m/sec). Figure 21 shows the relationship between depth of flow (d/D) and the sewer pipe gradient needed to attain minimum scour velocity. Since Figure 21 is based on a Manning coefficient (n) of 0.01, a second graph (Figure 22) is provided for extrapolation to other Manning's constants. For example, if we assume a maximum daily flow depth of .3 which is typical of the sewers observed in the sewer survey, the sewer pipe gradient needed to scour accumulated deposits during the day is 0.0092 ft/ft. Applying a correction factor of 1.7 for a sewer pipe having a normal Manning's Coefficient of 0.013 results in an overall slope requirement of 0.0156 ft/ft. This slope is significantly higher than that used in conventional design practices.

A comparison between the conventional design method and the Foster-Miller design method for 600 feet (183 m) of 8-inch (20 cm) sewer pipe is shown in Figure 23. It is evident from this comparison that the new design methods will require more excavation and the frequent use of lift stations. Consequently, the cost of laying sewers according to the new design standards can be expected to be substantially higher than presently experienced.

The difference in cost between sewers laid according to the conventional design method and the proposed revised design standards will depend largely on the type of terrain and soil conditions. If the sewer is to be located in gently sloping terrain where the gradient of the ground line is nearly equivalent to the gradient required for scour velocity flows, then the cost differences will be minimal. However, if we take the case shown in Figure 23 where the gradient of the ground line is flat or nearly flat, the differences in cost can be substantial. Table 20 shows a sewer cost comparison based on the designs shown in Figure 23. The annual cost of the glass carrying sewer is seen to be significantly higher than conventional designs. The impact of this cost difference is more readily apparent if we assume there is one single family home located in every 60 feet (18.3 m) of frontage on the 600-foot sewer line. With 20 single family homes connected to the sewer and an annual cost difference of $2,120 per year, the cost per household to allow sewer transport of glass is $106 per year. This would double the total per household cost of a wet system, and this alternative must clearly be judged infeasible.

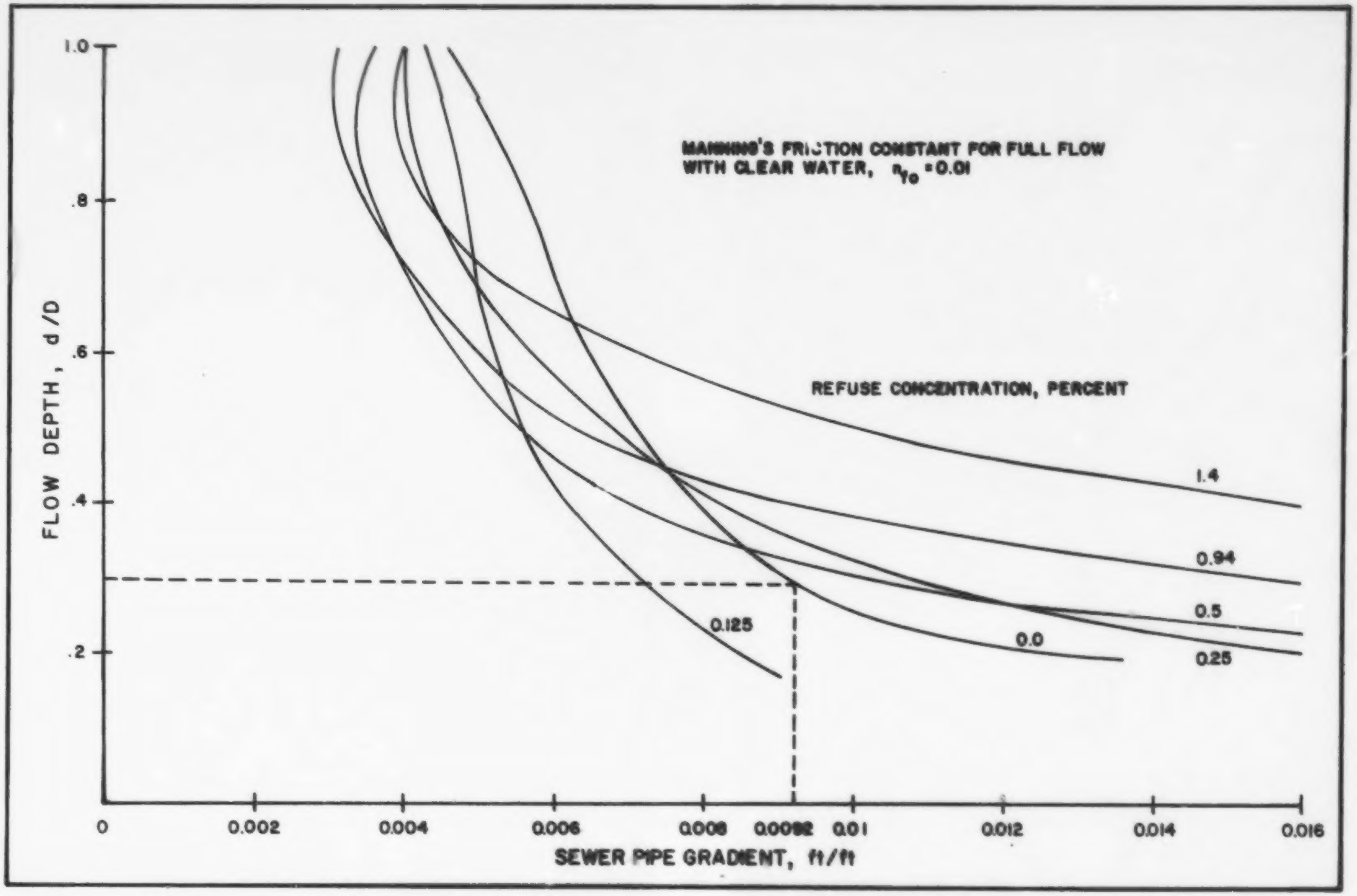

Figure 21: Sewer Pipe Gradient to Achieve Minimum Scour Velocity of 2.5 ft/sec for a Smooth Wall Pipe

Source: Guzdar and Rhee, op. cit., p. 113

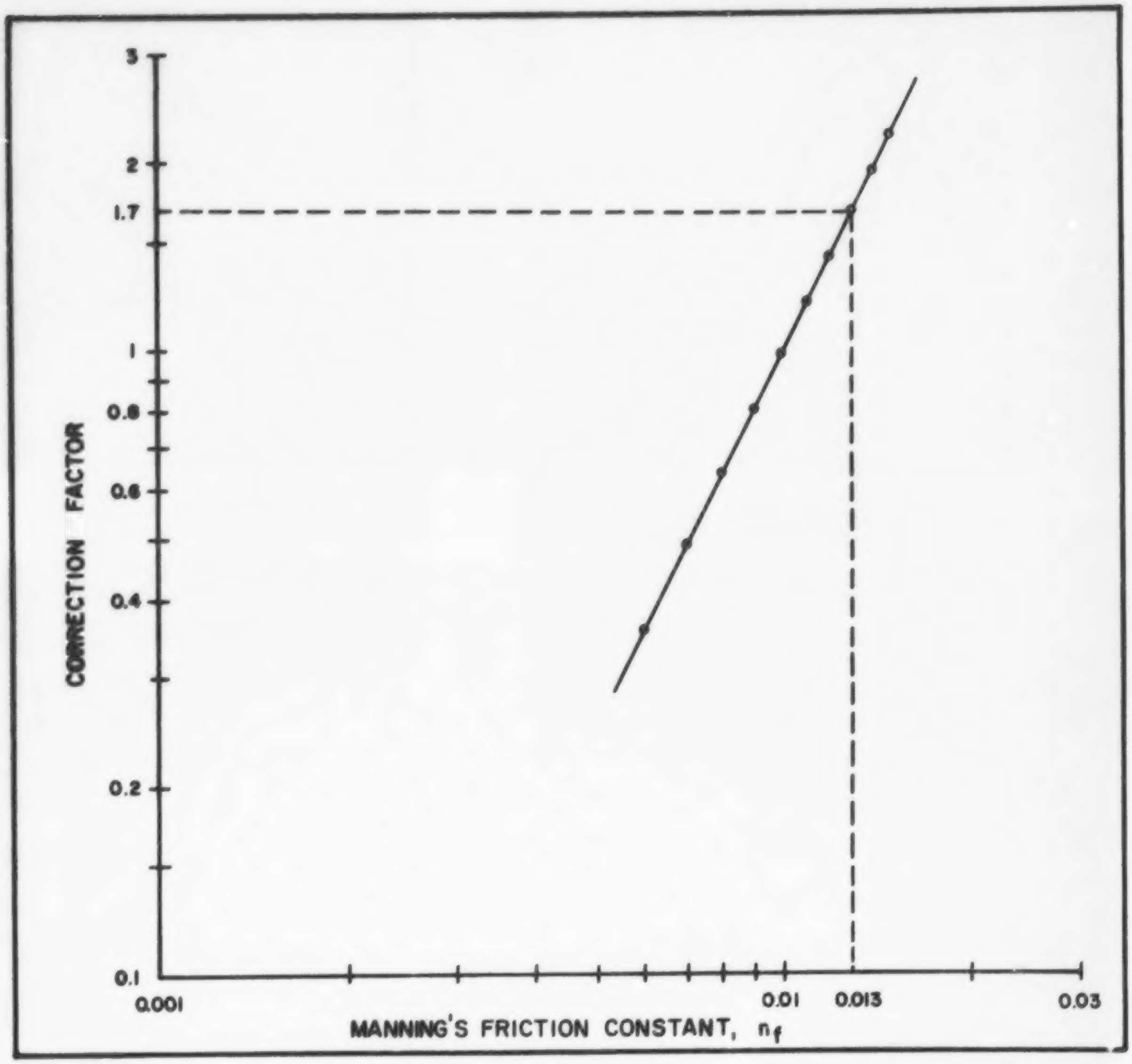

Figure 22: Correction factor for design charts showing minimum sewer gradient to scour

Source: Guzdar and Rhee, op. cit., p. 113

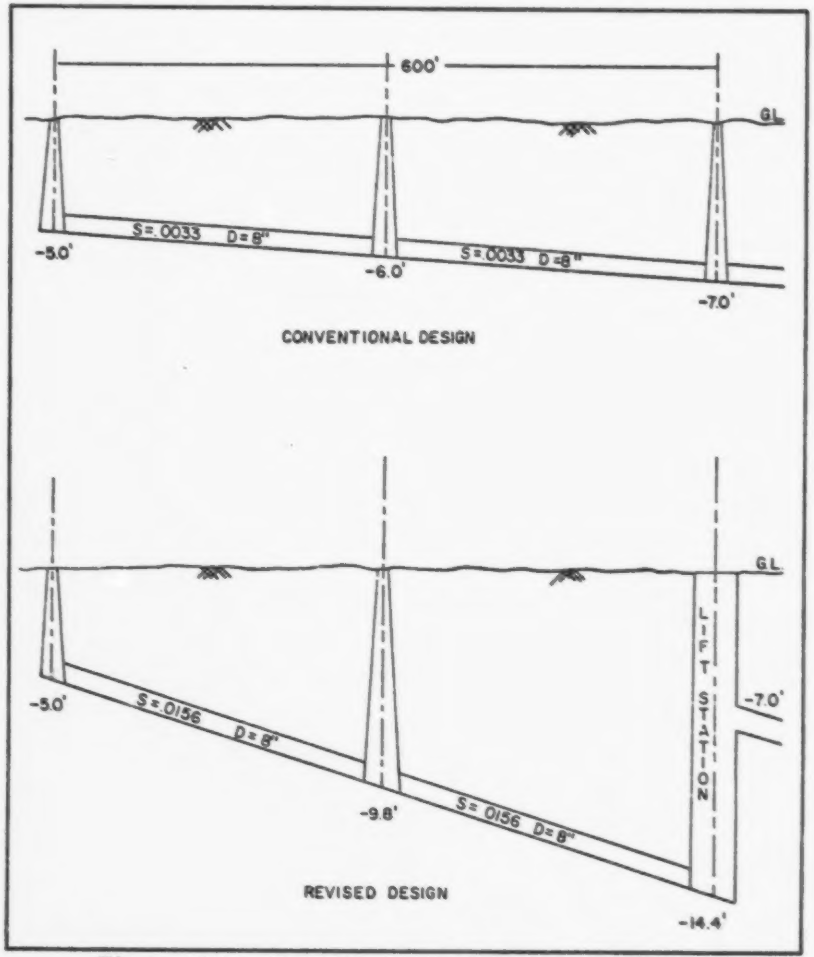
600'
GL
S=.0033 D=8"
S=.0033 D=8"
-5.0'
-6.0'
-7.0'
CONVENTIONAL DESIGN
GL
LIFT STATION
-7.0'
S=.0156 D=8"
S=.0156 D=8"
-5.0'
-9.8'
-14.4'
REVISED DESIGN

Figure 23: Comparison of design standards

Table 20: Sewer cost comparison

Cost of Conventional Sewer

ITEM	CAPITAL COST	ANNUAL COST
Installation of 8-inch AC pipe, including excavation and backfill (600 ft @ $13/l.f.)	$7,800	$495 (50 yrs @ 6%)
3 manholes @ $100/ft of depth	$1,800	$114 (50 yrs @ 6%)
TOTAL	$9,600	$609

Cost of Glass Carrying Sewer

ITEM	CAPITAL COST	ANNUAL COST
Installation of 8-inch AC pipe, including excavation and backfill (600 ft @ $20/l.f.	$12,000	$ 760 (50 yrs @ 6%)
2 manholes @ $100/ft of depth	$ 1,480	$ 94 (50 yrs @ 6%)
1 lift station, installed	$16,000	$1,395 (20 yrs @ 6%)
O & M cost (est.)	———	$ 480
TOTAL	$39,480	$2,729
ANNUAL COST DIFFERENCE		$2,120

In summary, it appears that redesigning gravity sewer systems to accommodate glass and other high specific gravity materials would be an extremely expensive venture. Periodic flushing of sewers appears to be a less expensive alternative. Otherwise glass, ceramic, and aluminum components of refuse should be eliminated as grindable items.

Grinding Water Investigation

The sewer survey discussed in the previous section showed that street sewers rarely, if ever, flow greater than half full. This is important because the limiting refuse concentration is strongly influenced by the flow depth. Foster-Miller Associates defines limiting refuse concentration as that concentration at which the friction resistance is the same as that for water and beyond which the friction resistance increases rapidly.[16] Consequently, if refuse mixtures above the limiting concentration are introduced into the sewerage system, reduced flow characteristics would result. Figure 24 shows the relationship between limiting refuse concentration and flow depth. For the depths of flow normally experienced in street sewers (between .1 and .3 d/D or d = 2 inches) it appears that the limiting concentration should be in the vicinity of 0.5 percent, instead of 1.0 percent as originally thought.

In the larger interceptors where greater depths of flow can be expected, the limiting refuse concentration may be as high as 1.5 percent if flowing full or near full.

Since the ground refuse must flow through the street sewers of residential areas before discharging into an interceptor, the lower limiting refuse concentration of 0.5 percent should govern the dilution water requirements at each grinder installation. This is unfortunate because the lower limiting refuse concentration (0.5 percent) is made to apply in an area where the least amount of dilution water is available. In street sewers, only residential flows and some infiltration can be expected whereas in the larger interceptors, dilution water is available from industrial and commercial sources as well.

The relationship between the amount of grinding water required and the percent solids content for various refuse generation rates is shown in Figure 25. This graph was developed from the equation:[17]

$$q = \frac{L(1-\Omega-\lambda)}{8.34\ \lambda}$$

where q is the gallons of grinding water required per capita per day, L is the pounds of refuse per capita per day, Ω is the moisture content of the refuse (assumed to be 20 percent) and λ is the grinding consistency ($0<\lambda<1$). Note that in order to satisfy the limiting refuse concentration of 0.5 percent, a grinding water requirement of between 20 and 90 gals/cap/day (76 and 342 ℓ/cap/day) is needed, depending on the refuse generation rate. For the average refuse generation rate of Springfield,

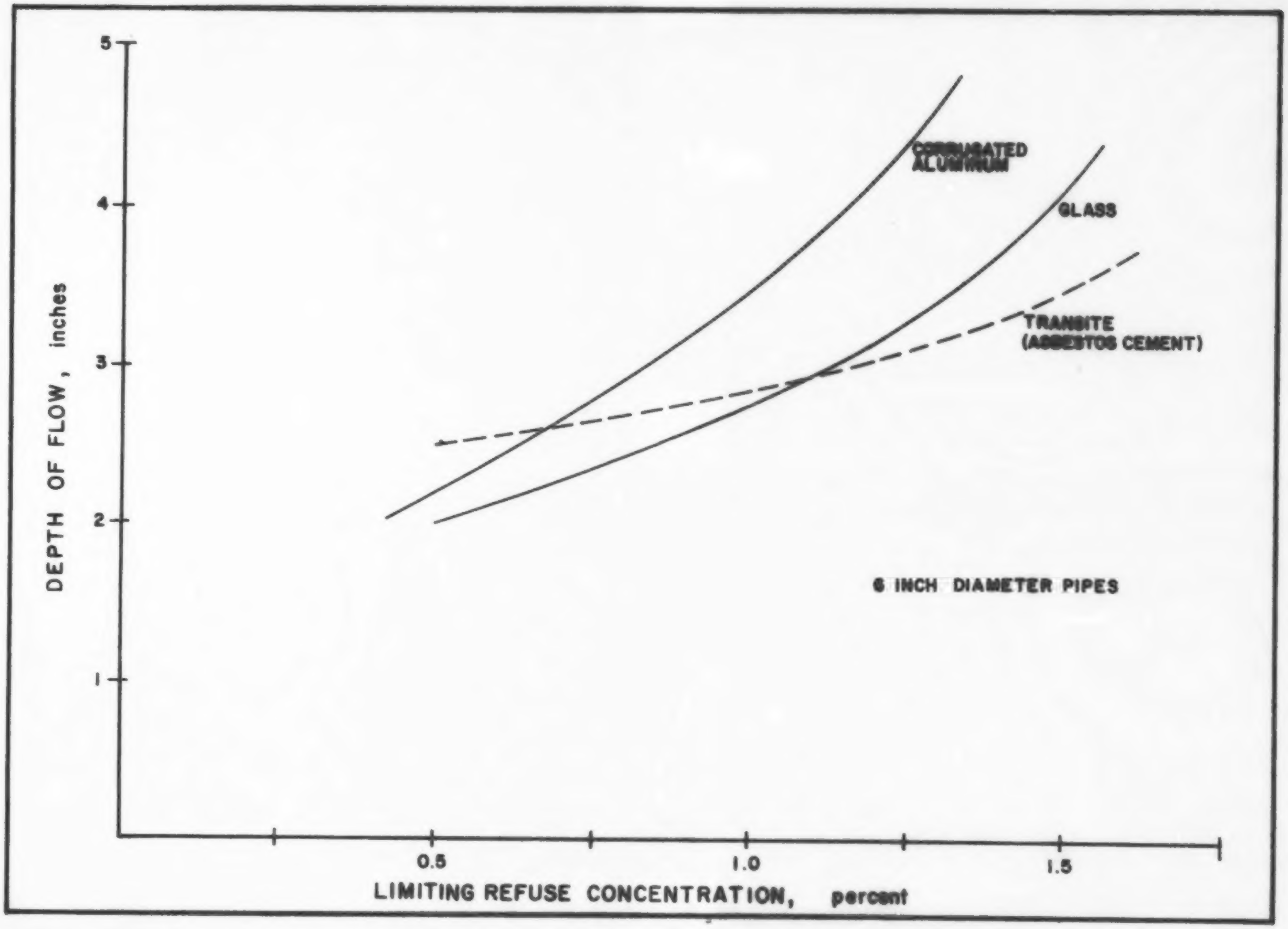

Figure 24: Limiting refuse concentration for hydraulic transport in sewers

Source: Guzdar and Rhee, op. cit., p. 98

which is 2.50 lbs/cap/day (1.14 Kg/cap/day), the amount of grinding water required is approximatley 48 gals/cap/day (182 ℓ/cap/day).

Because of this high grinding water requirement, Foster-Miller[18] suggested that household nonfecal wastewater be stored and reused for grinding. For the purpose of this analysis, nonfecal wastewater includes discharges from all plumbing fixtures except the toilet. Therefore, the total household water consumption required to allow refuse grinding using only nonfecal wastewater is the sum of the household grinding water requirement and the household fecal wastewater component. The household grinding water requirement can be determined by multiplying the number of persons per household times the per capita grinding water requirement determined from Figure 25. The household fecal wastewater component can be calculated based on an average toilet use of 4 uses/cap/day at 5 gals/use (19 ℓ/use). For the average household in Springfield with 3.63 persons per household (1970 Federal Census) the household water consumption rate needed to grind refuse is approximately 244 gals/HH/day (3.63 persons per household x (48+20) gals/cap/day). Note that an additional consumptive use component, which would include uses such as lawn sprinkling and car washing, is not included in the household water consumption rate because accurate data was not available.

In order to determine the actual household water consumption rates for typical residential areas in Springfield, water usage data was examined for 36 single family homes on Acrebrook Road and for 50 duplexes on Malden and Bloomfield Streets. Acrebrook Road is located in the Kensington area (see Figures 7 and 8, Chapter I). The water usage data was obtained from the meter readings recorded on the water billing sheets at the Springfield Water Department. The meter readings were taken in October and April on Acrebrook Road; therefore, this water usage data should reflect household uses only (not including lawn sprinkling, car washing, etc.). However, the meter readings for Malden and Bloomfield Streets were taken between January and July and should include some consumptive uses. The results of the water usage investigation are shown in Figures 26 and 27.

The household water consumption rate needed for grinding can be determined from the refuse analysis discussed in Chapter III. For Acrebrook Road, which is located in the Sixteen Acres Area, the average household refuse generation rate varies from a low of 36.61 pounds/week (16.1 Kg/week) in the winter to a high of 74.20 pounds/week (33.7 Kg/week) in the fall. These values must be reduced by 10 percent to obtain the grindable fraction of 33.0 and 66.8 pounds/week, respectively. With 3.63 persons per household in this area, the grindable per capita refuse generation rate varies between 1.3 lbs/cap/day (0.6 Kg/cap/day) in the winter to 2.6 lbs/cap/day (1.2 Kg/cap/day) in the fall. From Figure 25 the grinding water requirement at the limiting refuse concentration is then 24 gals/cap/day (91 ℓ/cap/day) in winter and 50 gals/cap/day (189 ℓ/cap/day) in the fall. Adding 20 gals/cap/day (76 ℓ/cap/day) to these figures for the fecal wastewater component and multiplying by 3.7 yields

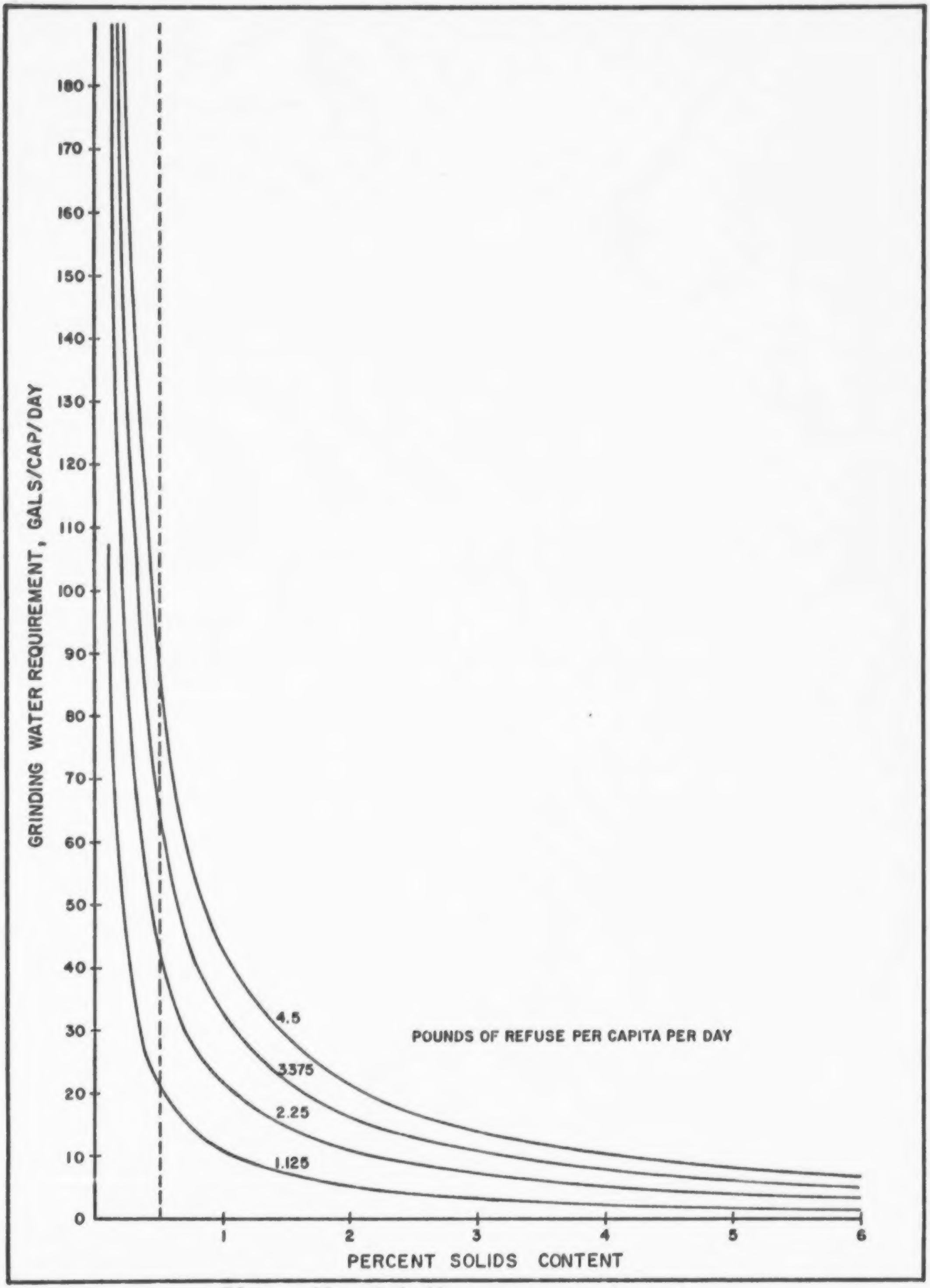

Figure 25: Grinding water requirement

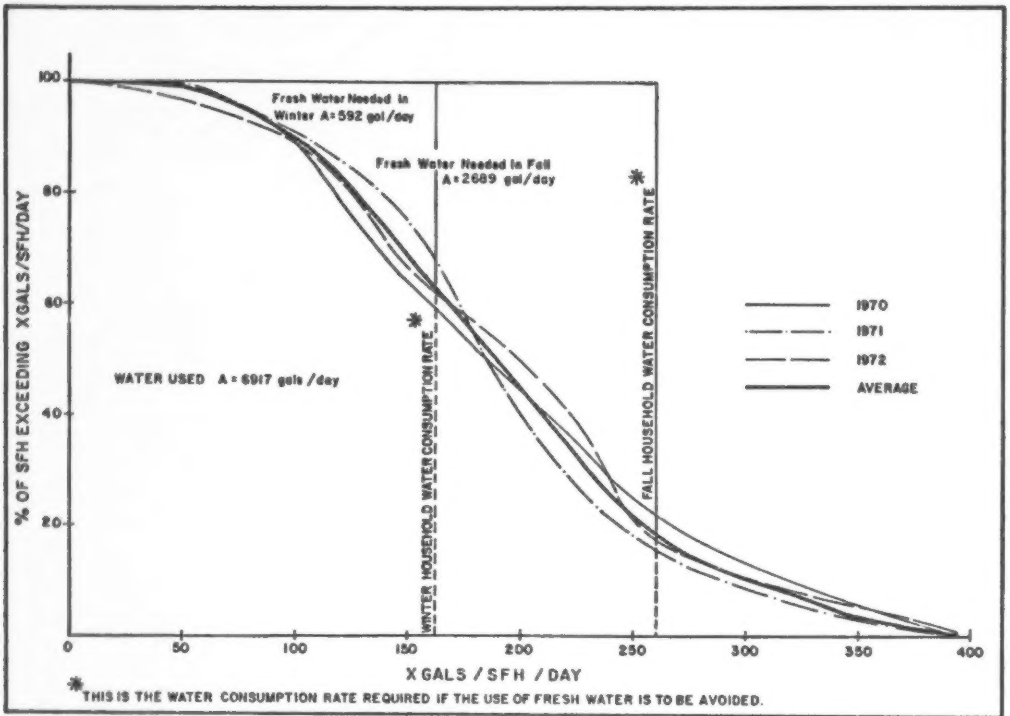

Figure 26: Water usage in 36 single family homes (Sixteen Acres area)

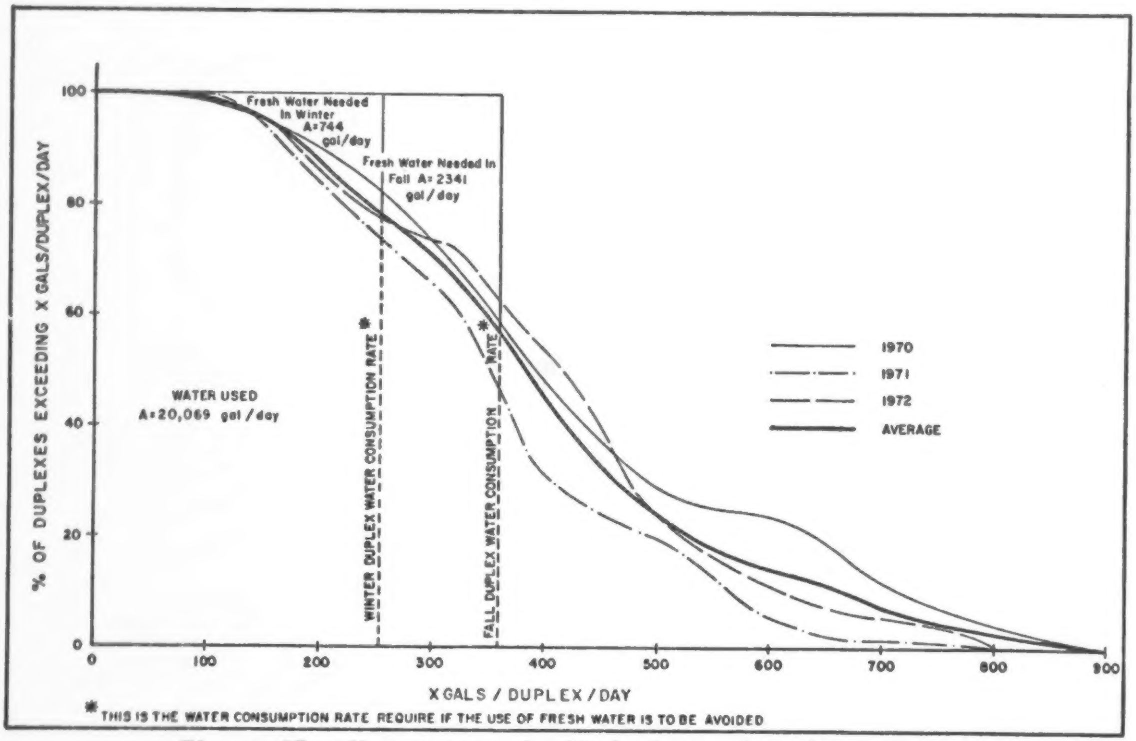

Figure 27: Water usage in 50 duplexes (Kensington area)

household water consumption rates varying from a low of 163 gals/HH/day (620 ℓ/cap/day) in winter to a high of 259 gals/HH/day (980 ℓ/cap/day) in fall. According to Figure 26, approximately 63 percent of the single family homes on Acrebrook Road would have enough nonfecal wastewater in the winter, but only 18 percent would have enough in the fall. Therefore, in both cases, substantial quantities of fresh water would be required to supplement the available nonfecal wastewater.

Following the same procedure for Malden and Bloomfield Streets located in the Kensington Area where there are 2.91 persons per household, the grindable per capita refuse generation rate varies between 1.3 to 2.1 lbs/cap/day (0.59 to 0.95 Kg/cap/day) for winter and fall respectively. This would require a household water consumption rate between 128 and 182 gals/HH/day (484 and 689 ℓ/HH/day), or between 256 and 364 gals/day (969 and 1378 ℓ/HH/day) for duplexes. According to Figure 27, approximately 78 percent of the duplexes would have enough nonfecal wastewater in winter and 57 percent in the fall. Although the need for supplemental freshwater does not seem as great in duplexes as in single family homes, it is substantial nevertheless. The reason for the greater percentage of duplexes meeting the household water consumption rates probably lies in the fact that the water usage data included some consumptive uses and there may also be less yard waste per person in duplexes since two families occupy the same lot.

If there is not enough nonfecal wastewater in all homes for refuse grinding purposes, freshwater must be used. The amount of fresh water needed for the 36 single family homes on Acrebrook Road and the 50 duplexes on Malden and Bloomfield Streets can be determined from Figures 26 and 27. The areas bounded by the water usage distribution curve and the household water consumption rates needed for grinding represent the fresh water needed in gallons per day. The area beneath the curve represents the actual water used by the 36 homes or 50 duplexes per day. Figures 26 and 27 show the water used and the freshwater needed for each area and for each season. For example, the 36 single family homes on Acrebrook Road would consume an additional 2689 gallons (10,178 ℓ) per day in the fall if grinders were installed. A ratio of the fresh water needed over the actual water presented used reveals that the single family home area would require an 8.5 percent increase in water consumption in the winter and a 39 percent increase in the fall. The duplex area would require a 3.7 percent increase in the winter and a 12 percent increase in the fall. Considering that over 65 percent of the housing units in the city of Springfield are either single family homes or duplexes, this would represent a large increase in total water demand. Moreover, while increased flows could probably be accommodated in the lateral sewers without difficulty (because, as shown by our survey, they rarely flow at more than half depths), there may be problems in interceptors that are more likely to reach flows nearer their design value, and of course, the total inflow at the sewage treatment plant would also increase. A conclusion from this analysis is that much of the garden wastes collected in the fall, which is largely responsible for the higher refuse quantities in that season, cannot be ground for reasons of unacceptable freshwater demands, and would therefore need a special conventional collection.

A proper discussion of the previous analysis would not be complete without mentioning the possibility of a more optimistic conclusion if correlative data between refuse generation and water usage were available. It may be that those homes with low water usage rates may also have low refuse generation rates. In that case, the average refuse generation rates used in the previous analysis would not apply and less fresh water would be needed. This deficiency in the data is addressed further in our recommendations for additional research to resolve as yet unanswered technical uncertainties.

Hydraulic Transport at Higher Than Critical Concentrations

The large quantity of dilution water required to maintain hydraulic flow characteristics similar to water raises the question as to the impact of depositing refuse in sewers at concentrations higher than the limiting refuse concentration (0.5 percent). If refuse concentrations of 1 percent and more were hydraulicly transportable, substantially less dilution water would be required. From Figure 25, it can be seen that at 1 and 2 percent refuse concentrations, dilution water requirements can be reduced by 50 to 75 percent respectively. This would mean that a much larger percentage of homes would possess the necessary dilution water and very little fresh water would be needed. Also, the laboratory experiments of Foster-Miller have shown that flows at higher refuse concentrations (2 percent and above) have the ability to maintain heavier particles in suspension. This would eliminate the need to attain a specific scour velocity to remove settled materials. However, these heavier particles would likely settle out as the mixture is diluted further downstream.

Foster-Miller also noted that head losses increase dramatically at refuse concentrations above the limiting refuse concentration. Consequently, mixture velocities would be less than for sewage alone, or for refuse mixtures below the limiting refuse concentration. Depending on the condition of the sewer, this could cause more frequent blockages. Also, the detention of sewer flows may encourage septic conditions which would be more objectionable in residential areas. Although sewers can be expected to flow fuller as a result of the decrease in velocity, this is not expected to be a problem since most street sewers are overdesigned as evidenced in the sewer survey, and rarely flow above half-full. The impact of various concentrations of refuse on the relative depth of flow and relative velocity is shown in Table 21 for $Q/Q_f = 0.2$.

Although there are many benefits to be derived from grinding and transporting refuse mixtures at higher than critical concentrations, it is difficult to make judgments of the technical feasibility of this idea unitl further experiments have been conducted.

Table 21: Effect of refuse concentration on d/D and V/V_f for $Q/Q_f = 0.2$

Refuse Concentration %	d/D	V/V_f
0.00	.32	.70
0.25	.32	.67
0.50	.32	.68
1.00	.34	.61
1.40	.40	.44
2.00	.76	a

Derived from Foster-Miller, _op. cit._, Figures 43 and 45

[a] Value not given

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CHAPTER IV

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2. "Report on Combined Sewer Overflows for the City of Springfield, Massachusetts," by Camp, Dresser and McKee, Inc., October 1971.

3. *Ibid*.

4. Guzdar, A. and S. Rhee, "Feasibility of Hydraulic Transport and Treatment of Ground Household Refuse Through Sewers," report by Foster-Miller to EPA Solid Waste Research Laboratory, Cincinnati, Ohio, January 1973.

5. *Ibid*.

6. "Design and Construction of Sanitary and Storm Sewers," WPCF Manual of Practice No. 9, Water Pollution Control Federation 1969, p. 128.

7. Guzdar, A., and S. Rhee, *op*. *cit*.

8. However, it should be pointed out that the actual velocity of flow with refuse will be slightly higher since the depth of flow with refuse can be expected to increase somewhat. The actual depth of flow with refuse can be determined from the relationship d/D vs Q/Q_{fo} (Figure 44 of Foster-Miller Report, *op*. *cit*.) where Q/Qfo is assumed constant. For the relative depth ratio d/D observed in the sewer survey the maximum depth change would be less than 2 percent.

9. Personal conversation with Mr. James I. Moylan, Deputy Superintendent of Sewers, Springfield, Massachusetts, September 27, 1973.

10. Personal conversation with Mr. H. E. Hafley, New England Regional Manager of Penetryn System, Inc., Sewer Services Division, September 21, 1973.

11. Personal conversation with Mr. James I. Moylan.

12. "Jet-Vacuum Sewer Cleaning," *The American City*, Vol. 86, No. 7, July 1971, p. 83.

13. Personal conversation with Mr. H.E. Hafley.

14. "Jet-Vacuum Sewer Cleaning," *op*. *cit*.

15. Personal conversation with Mr. James I. Moylan.

16. Guzdar, A., and S. Rhee, *op. cit.*, p. 90.

17. Meier, P. M., J. Kühner and C. J. Martel, "A Preliminary Assessment of Wet Systems for Residential Refuse Collection," Report by Curran Associates, Inc., to EPA Solid Waste Research Laboratory, March 1974.

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CHAPTER V

TREATMENT

Existing Situation

Before one can knowledgeably assess the effect of ground refuse additions on a municipal sewage treatment system, it is necessary to have a detailed understanding of present plant conditions, including any planned modifications or changes. At the present time, Springfield utilizes two wastewater treatment facilities, each providing primary treatment for domestic sewage and most of the industrial wastes in the city.

The smaller facility, called the Indian Orchard Treatment Plant, is located in the northeast section of the city on the Chicopee River. At present the plant handles only domestic sewage from the Indian Orchard section of Springfield, and wastes from the Monsanto industrial complex are dumped directly into the river. The nominal capacity of the plant is estimated at 3.0 mgd (11,355 m^3/day). The treatment process consists of screening, grit removal, and sedimentation prior to discharge of the unchlorinated final effluent. Settled sludge is digested, dried on glass-covered drying beds, and used as fill.

The major portion of Springfield's waste load is treated at the main treatment plant located on the Connecticut River at Bondi Island in Agawam. In addition to Springfield, the plant presently treats wastes from West Springfield, Agawam, and parts of East Longmeadow. By agreement with each of these municipalities, the plant handles average sewage flows of 4.1 mgd, 1.0 mgd, and 0.667 mgd, respectively (or 15518.5, 3785, and 2525 m^3/day). The flow from each town is metered separately and charges apportioned accordingly.

The treatment facility itself is quite old, having been completed in 1940 as a Works Progress Administration (WPA) project. It provides units for coarse screening, grit removal, comminution of solids, and primary settling. Sludge handling facilities include heated digestion tanks, elutriation tanks, a vacuum filter, and land disposal site. There is no chlorination before discharge. Figure 28 provides a schematic of the present operation.

The design capacity of the existing plant is rated at 30 mgd. Flows in excess of this figure are regularly recorded, with a resulting decrease in removal efficiency. Flows beyond 45 mgd (170325 m^3/day) are automatically bypassed directly to the Connecticut River.

The various components of the treatment plant are more particularly described as follows:

Coarse Bar Racks - Three 6-foot wide racks with 3-inch clear openings.

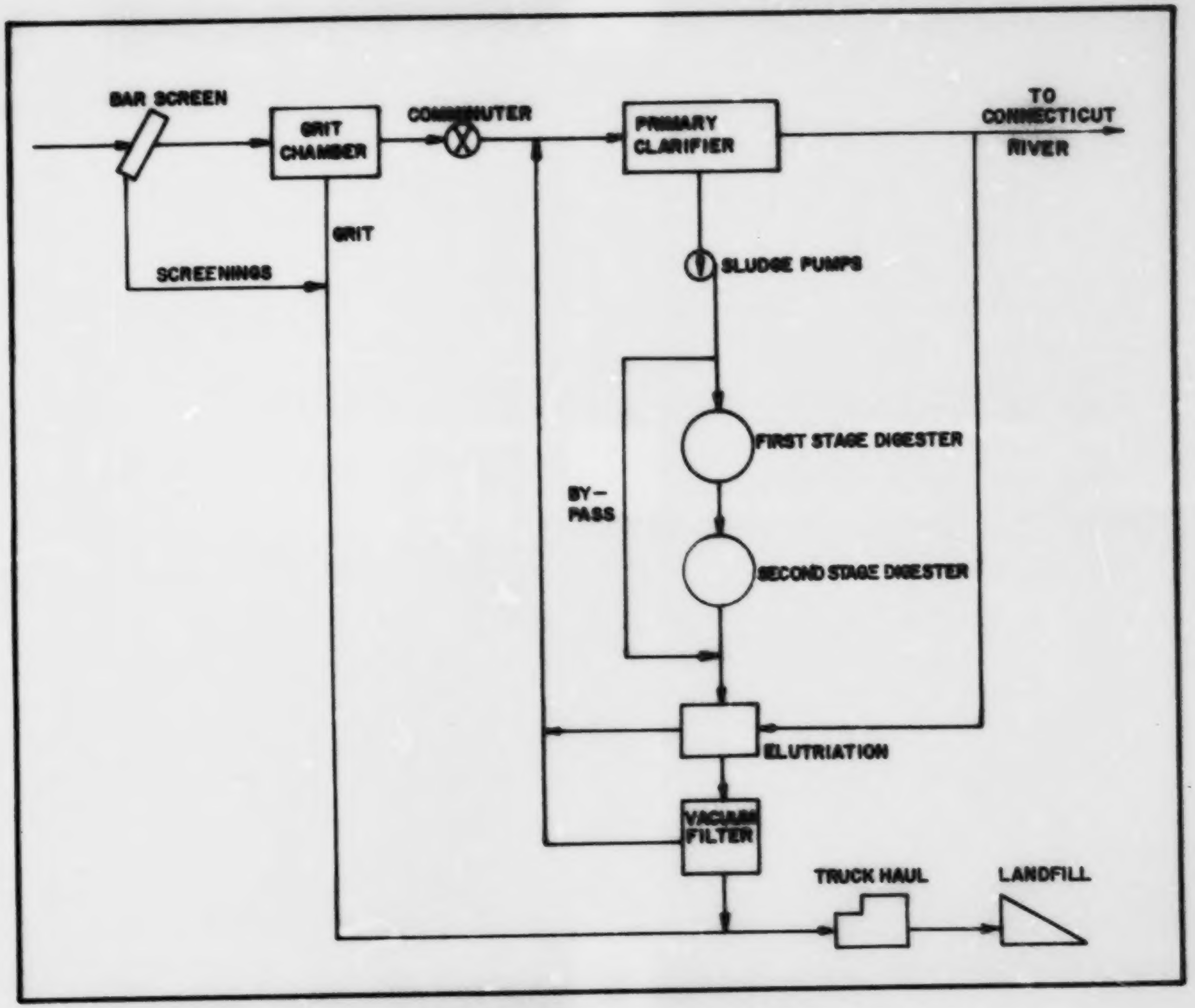
BAR SCREEN
GRIT CHAMBER
COMMINUTER
PRIMARY CLARIFIER
TO CONNECTICUT RIVER
GRIT
SCREENINGS
SLUDGE PUMPS
FIRST STAGE DIGESTER
BY-PASS
SECOND STAGE DIGESTER
ELUTRIATION
VACUUM FILTER
TRUCK HAUL
LANDFILL

Figure 28: Existing treatment plant

Grit Chambers - Two 40-foot square units. Each has a maximum capacity of about 64 mgd.

Comminuters - Three 36-inch units. Each has a maximum capacity of about 20 mgd at available head.

Settling Tanks - Four 50 feet x 115 feet rectangular units equipped with flights and scrapers.

Sludge Digestion - Four 55-foot diameter circular units with 21 foot side water depth (SWD). Two sets of 2 units in series. The total capacity is 190,000 cubic feet. All units are equipped with floating covers. Gas collection and storage facilities are provided.

Elutriation Tanks - Two 40 feet x 12 feet rectangular units with 12-foot SWD. The units are equipped with sludge collectors.

Sludge Drying - One vacuum filter with 300 square feet of filter area is in use. It has a capacity for filtering raw primary sludge of about 2,400 pounds of dry solids per hour. Ferric chloride storage and feeding facilities are available.

The primary factor limiting the treatment capacity of the existing plant is the sludge disposal system. The digestion process is impeded when large volumes of sludge are fed to the digesters. Also, one unit must be dewatered each year for grit removal. As a result of the digesters' inability to handle the present sludge volumes, approximately half of the settled sludge is now by-passed directly to the elutriation tanks. There the two sludge streams, digested and raw, are mixed prior to vacuum filtration.

A computer model of the system was developed which further stressed the inadequacy of the present removals.[1] On the basis of the model, it was estimated that only 48 percent of the BOD is removed by the existing facility. The theoretical addition of 2.56 pounds of refuse per capita per day (1.15 Kg/cap/day) would abviously aggravate the present plant limitations even further.

Proposed Sewage Treatment Plant

In light of the inadequacy of the present plant, the city of Springfield has contracted for development of a new treatment facility. The plan calls for abandonment of the Indian Orchard facility, and construction of a new plant at the Bondi Island site. This new plant would provide secondary treatment for all the present participant towns and, in addition, would include the towns of Ludlow and Longmeadow and the industrial flow from the Monsanto Chemical Company. The rates of flow and strengths of wastewater projected for each contributor for the design year (1990) are listed in Table 22.

Table 22: Estimated flows and wasteloads for 1990 design year
(Source: CDM, op. cit.)

	Flow, mgd[a] Average	Peak	BOD lbs/day[b]	S.S. lbs/day[b]
Ludlow	2.7	8.2	4,500	3,380
Monsanto	8.8	19.1	48,500	23,500
Indian Orchard	3.5	15.7	7,300	5,850
East Longmeadow	2.3	7.4	3,400	4,400
Springfield	31.7	91.7	45,700	44,500
West Springfield	9.0	16.9	11,300	16,200
Agawam	6.1	15.4	11,800	14,500
TOTAL	64.1	174.1	132,500	112,330

[a] Mgd x 3,785 = m^3/day

[b] lbs/day x .454 = Kg/day

In order to develop design factors for a full-scale plant, it was first necessary to determine the compatibility of the Monsanto wastes with the sanitary sewage from the city of Springfield and neighboring communities. As an initial step, the city's consulting engineers conducted a pilot plant study, with the resultant projection that conventional activated sludge processes would be sufficient to provide 85 percent removal of the projected BOD loading.[2] A further study[3] of the Connecticut River in the area of the proposed plant concluded that 85 percent BOD removal would not jeopardize the C classification of the river. This classification requires that the water be suitable for recreational boating, a habitat for wildlife and common food and game fish indigenous to the region, and certain industrial cooling and process uses. More particular criteria state that DO (dissolved oxygen) should not be less than 5 mg/ℓ (milligrams per liter) for at least 16 hours of any 24-hour period, nor less than 3 mg/ℓ at any time.

Inasmuch as it was determined that the classification of the Connecticut River below Springfield could be met by an 85 percent reduction in BOD of the wastes entering the Bondi Island Treatment Plant, the proposed facilities were designed to accomplish this removal. The individual types of treatment units chosen for the plant were determined as a result of the pilot plant studies previously mentioned. The plant as designed will consist of bar screens, grit separation units (cyclones), primary settling tanks, aeration tanks, flocculation tanks, final settling and chlorination facilities. Pumping units will be provided to discharge the plant effluent into the Connecticut River during flood seasons. The sludge handling facilities will include gravity thickeners for primary sludge, flotation thickeners for waste activated sludge, holding tanks for both primary and waste activated sludge, and wet oxidation facilities to sterilize and reduce sludge volumes and thus the size of the vacuum filters. A process schematic of the proposed 64.1 mgd (264,618 m^3/day) waste treatment plant is shown in Figure 29.

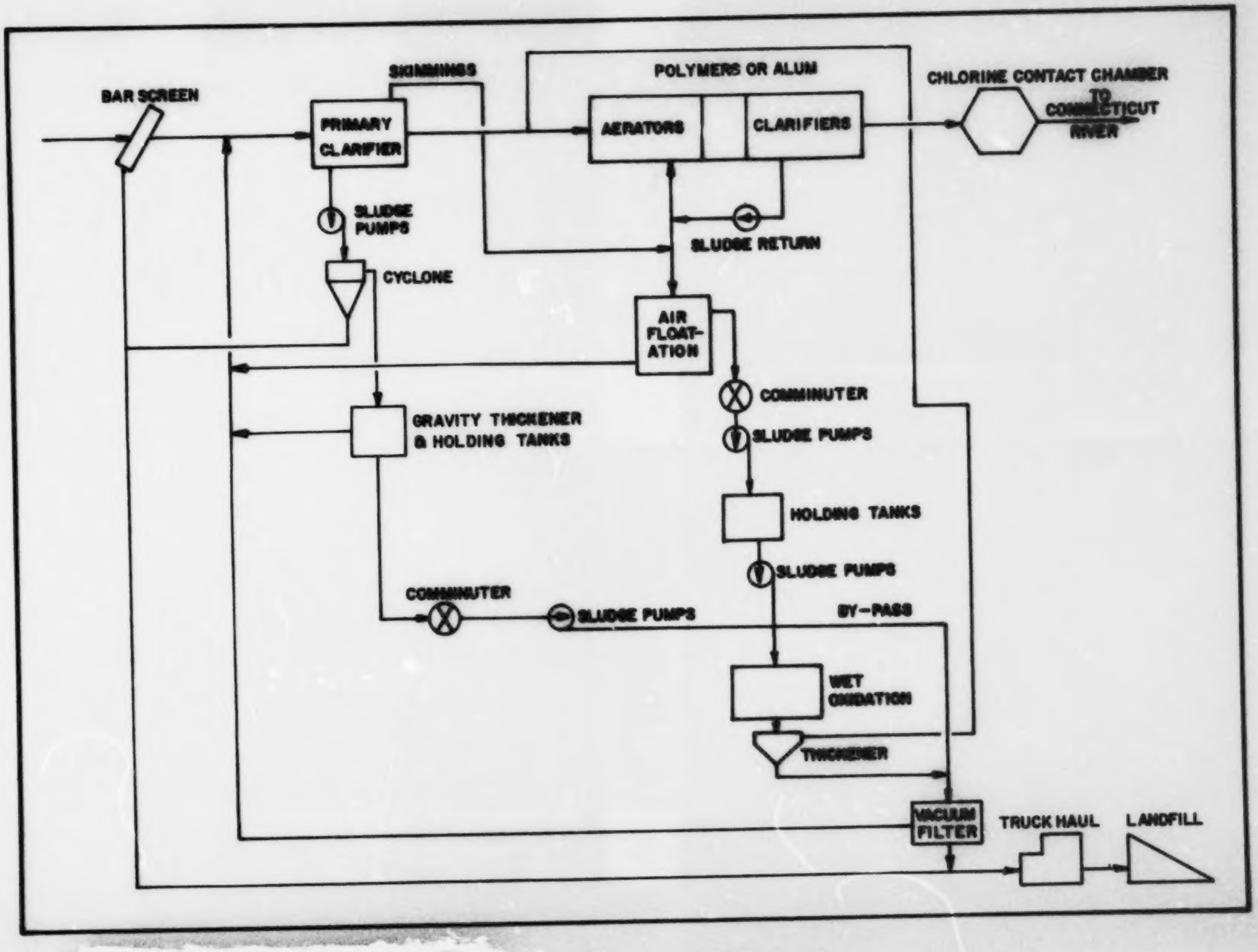
BAR SCREEN
SKIMMINGS
PRIMARY CLARIFIER
POLYMERS OR ALUM
AERATORS
CLARIFIERS
CHLORINE CONTACT CHAMBER
TO CONNECTICUT RIVER
SLUDGE PUMPS
SLUDGE RETURN
CYCLONE
AIR FLOAT-ATION
COMMINUTER
SLUDGE PUMPS
GRAVITY THICKENER & HOLDING TANKS
HOLDING TANKS
SLUDGE PUMPS
COMMINUTER
SLUDGE PUMPS
BY-PASS
WET OXIDATION
THICKENER
VACUUM FILTER
TRUCK HAUL
LANDFILL

Figure 29: Planned treatment plant

At the time of this writing, the contract for the plant has been awarded, and it is planned that construction will begin in October of 1973. It is estimated that it will be three years before the facility can start full operation.

Generation of Input Parameters

In order to estimate what effect the inclusion of ground refuse would have on the proposed plant's performance, it is necessary first to model the plant as it is presently envisioned and then to adjust the input quality parameters to reflect the additional load occasioned by 1.79 pounds of ground refuse per capita per day (1.15 Kg/cap/day).

Again using the modified executive treatment plant model developed in early stages of our research, a model of the planned treatment facility was constructed.[4] Characteristic concentrations of the influent stream were based on results obtained from the pilot plant study and also on existing records. Once this basis was established, it was then possible to adjust the influent stream quality parameters to reflect any desired loading.

As mentioned in the Phase I report,[5] there is a critical lack of information on the character of ground refuse in sewage. For this reason, figures dealing with the physical and chemical characteristics of ground refuse in sewage must necessarily be best estimates based on the limited information which does presently exist.

Because of the large amounts of solids and floatables present in sewage containing ground refuse, and the subsequent problems these solids cause in laboratory analyses, all past tests have been performed on primary effluents. In the Metcalf and Eddy study,[6] ground refuse was added to Boston sewage in varying concentrations ranging from 0.25 percent to 1.0 percent based on a per capita daily wastewater generation of 100 gcpd (378.5 ℓ/cap/day). In Springfield, records shown that about 140 gallons (530 litres) of sewage are generated per person per day. Thus, at a refuse generation rate of 1.79 lb/cap/day (0.81 Kg/cap/day) the loading on the treatment plant will average only about .2 percent by weight.

In order to estimate the quality parameters associated with a refuse-sewage stream of this strength, it is necessary to estimate the nature of the primary effluent and then to work back, using a solids balance similar to that outlined in the Phase I section of the report, to obtain reasonable values for the influent flow. Following this procedure, estimated concentrations associated with a 1.79 lb/cap/day (0.81 Kg/cap/day) loading in the Springfield sewerage system were developed. These concentrations, along with those of the sewage flow, are listed in Table 23. The 1.79 lb/cap/day is based on the assumption that of the total 2.56 lb/cap/day generation rate developed in Chapter III, 10 percent by weight is non-grindable and 20 percent by weight is moisture. In the following analysis, therefore, the lb/cap/day figures used are on a dry weight basis.

Table 23: Present and projected waste concentrations

Parameter	mg/ℓ Present Sewage	 With .2% Refuse
Solid Organic Carbon	105.0	181.0
Solid Nonbiodegradable Carbon	30.0	60.0
Solid Organic Nitrogen	10.0	12.0
Solid Organic Phosphorus	2.0	4.0
Solid Fixed Matter	73.0	473.0
Solid BOD (SBOD)	93.0	113.0
Volatile Suspended Solids (VSS)	91.0	1,041.0
Total Suspended Solids (TSS)	164.0	1,514.0
Gross Suspended Solids (GSS)[a]	0.0	525.0
Normal Suspended Solids (NSS)[a]	154.0	699.0
Heat, BTU/gallon	616.0	5,692.14
Grit[a]	10.0	290.0
Dissolved Organic Carbon	43.0	73.0
Dissolved Nonbiodegradable Carbon	11.0	20.0
Dissolved Nitrogen	19.0	20.0
Dissolved Phosphorus	5.5	8.25
Dissolved Fixed Matter	259.0	500.0
Alkalinity, mg/l as $CaCO_3$	92.0	250.0
Dissolved BOD (DBOD)	40.0	115.0
Dissolved Organic Matter	160.0	320.0

[a] For definitions of these parameters, see Meier and Fisette, op. cit., Chapter II.

Effects of Refuse on the Proposed Bondi Island Plant

The imposition of ground domestic refuse on the proposed Bondi Island Treatment Plant will affect some processes to a greater degree than others. It is our intent, through the computer model, to highlight those plant functions which would be most severely limited. Once these problem areas have been designated, it is then possible, again with the help of computer simulations, to try various alternative schemes in order to obtain the best quality effluent at the least possible cost.

It should be clear from the outset that we are not recommending changes or modifications in the design of the Bondi Island Sewage Treatment Plant. Rather, we hope to focus on those processes which would be inadequate only if a wet system of refuse disposal were to be implemented in the city of Springfield.

As might be expected, the increased concentrations of solids and BOD will greatly influence the sizing of many plant components, especially sludge handling processes. It is estimated that a loading of 1.79 pounds of ground refuse per capita per day (0.81 Kg/cap/day) will result in an average total solids concentration of 1514 mg/ℓ entering the plant. This figure is roughly ten times the present loading. A great portion of these added solids will be in the form of grit from ground glass (290.0 mg/ℓ), and gross solids from packaging and the like (525.0 mg/ℓ). The quantities of these two constituents place particular constraints on the design and operation of the grit handling facility. The proposed plant will feed all the primary sludge, including the grit, to a cyclone separator. Although this scheme should provide adequate removal for all projected grit quantities resulting from sewage alone, the greatly increased concentrations expected as the result of ground refuse addition could cause numerous problems with clogging and inefficient grit separation. Rather than increase the capacity of the cyclone separators, a cheaper and more efficient solution was found to incorporate a conventional aerated grit chamber and grit washer prior to primary settling. Such a modification will have the effect of removing grit prior to primary sludge pumping, and should provide a more effective operation under the changed conditions anticipated with ground refuse additions.

As presently envisioned, the proposed plant will utilize two separate sludge thickeners. Primary sludge will flow from the cyclone separator directly to a series of gravity thickeners. Waste activated sludge, on the other hand, will be thickened to about 4 percent solids by use of six air flotation units. There are holding tanks for each stream of thickened sludge prior to mixing and injection into the wet air oxidation unit. The ratio by weight of dry solids of primary to waste activated sludge in a conventional wastewater treatment plant handling the sewage alone is about 1.2:1, or even 0.5:1.[7] By comparison, the ratio which could be expected by adding 1.79 lb/cap/day (0.81 Kg/cap/day) ground refuse soars to about 12:1, primary sludge to secondary. At such high ratios, the cost-effectiveness of two separate thickening processes would appear questionable. Because the waste activated sludge portion is so small, it can be mixed with the primary sludge and then thickened together with little loss of efficiency, but at great cost savings.[8] Therefore, should a wet system of refuse disposal be initiated, it would be more economic to thicken both sludge streams together in a gravity thickener. This is confirmed by the cost analyses presented below.

The wet-air oxidation process operates under the principle that organic substances may be oxidized under high pressures at elevated temperatures with the sludge in a liquid state by feeding compressed air into the pressure vessel. The process was developed in Norway for pulp-mill wastes, but has been revised for the oxidation to raw sewage sludge pumped directly from the primary settling tank or thickener. Combustion is not complete. For the Springfield plant, a low pressure oxidation unit has been specified. Performance characteristics of such a unit include a 15 percent reduction of Chemical Oxygen Demand (COD) and a 30 percent destruction of the insoluble volatile matter. The end product of the process is a sterile dewaterable and oxidized liquid mass. As a result of the rather low degree of oxidation and the destruction of the volatile solids, a good portion of the solid COD is converted to dissolved COD and returned with a supernatant from the vacuum filter to the head of the plant. For normal sewage this additional COD loading is not significant, but when ground refuse has been added to the sludge stream, the COD of the supernatant can be expected to be of such large magnitude as to severely affect the aeration processes to which the vacuum filter supernatant is returned.

This would not be as serious a problem if anaerobic digesters were used since the digesters convert organic acids to methane gas and carbon dioxide, and thus remove a great deal of the COD from the return stream. As noted by Kos et al.[9] there is sufficient evidence to show that ground refuse can be satisfactorily digested with sewage sludge. Moreover, contingent on a favorable local market this technique can provide a valuable commodity through methane gas production. For these reasons, we would recommend that should ground refuse be added to the sewage stream at Bondi Island, anaerobic digesters would provide a better solution than wet-air oxidation. However, if the methane gas would yield less than $0.80/1000 cu. ft., our detailed studies on sludge handling show that the digester should be omitted, with the thickener underflow fed directly to holding tanks and vacuum filters.

In addition to those processes already mentioned, many other plant functions would need to be enlarged to handle the additional load; foremost among these are the sludge holding tanks, sludge pumps, thickeners and the aeration basins.

The computer analyses indicate that as a result of ground refuse additions, dissolved BOD loadings into the aerator will increase three-fold and solid BOD would increase by a factor of 1.2. Total solids to the aerator would increase by a factor of about 4.5. In order to achieve the same degree of BOD removal as the proposed plant with just sewage, the aeration basin would need to be substantially enlarged. This seems in sharp contrast to the primary settler, which would not need to be enlarged. The reasons for this apparent discrepancy is that using existing settling curves, the great majority of solids added by the ground refuse would either float to the surface or settle easily within the alotted detention period. This fact is further detailed by comparing solids concentrations in primary and secondary sludge stream for the two cases: with refuse and without. With ground refuse added, the total solids in the primary sludge stream increases eleven-fold over that expected from just sewage. On the other hand, the solids in the waste activated sludge stream remain virtually the same for both cases.

This increase in primary sludge solids will affect the sizing of all subsequent sludge handling processes. Accordingly, there will be increased capacity and cost associated with the sludge pumps, sludge holding tanks, thickeners, digesters and vacuum filters. Specifics regarding these processes, including landfill requirements, are discussed in detail in the separate report on sludge handling and disposal.[11]

Figure 30 is a schematic of the recommended plant. We have indicated that a microscreen be used just prior to chlorination. The effect of the screen would be to compensate for seasonal variations and to polish the effluent by removing many of the trace solids (cellulose) which might remain. The result is that the plant as a whole will remove 92 percent of the BOD from the refuse-sewage mixture and will provide an effluent which is at least as good as that forecast for the proposed plant with sewage alone.

In addition to those quality parameters outlined in Table 23, there remain a number of variables associated with ground refuse in sewage about which we have little or no knowledge. These include possible effects connected with grease and oil, toxic materials and heavy metals. It is important that a complete investigation into the nature of ground domestic refuse in sewage be conducted in order that effects on the various treatment processes associated with these additional parameters might be fully evaluated. This is a point that has been fully addressed in the preliminary phase of our investigations.[12]

Seasonal Variations. As detailed in Chapter III of this report, one can expect substantial seasonal variations in both the character and quantities of refuse generated. Just as these variations affect present disposal techniques, they would also affect treatment plant operation should these peaks be ground and discharged into the sewers.

Table 24 shows the expected seasonal variations in influent quality parameters, given that the fractions of each refuse category ground remain constant throughout the year.[13] Clearly, the peak seasonal load would thus be expected in the fall.

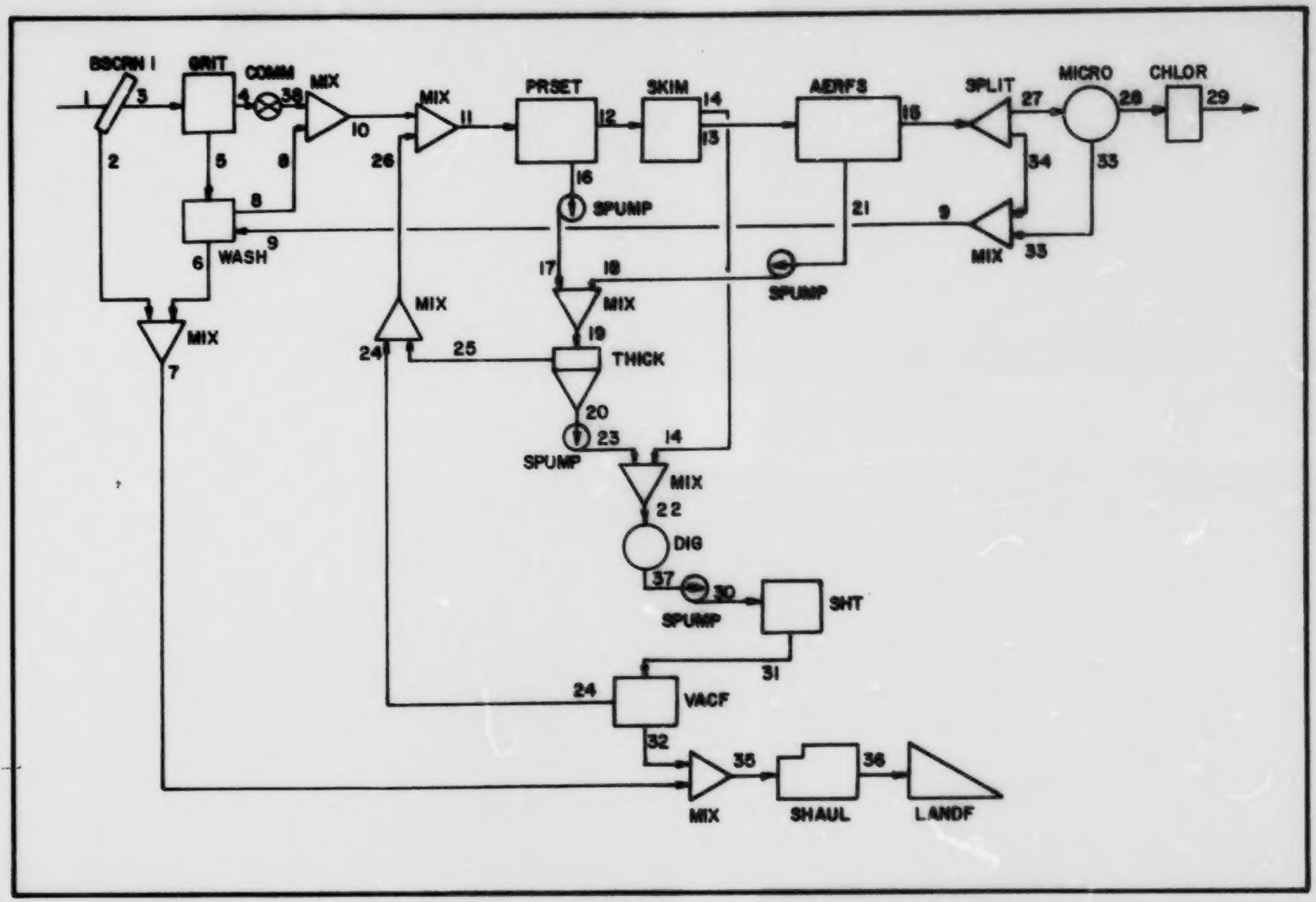
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Figure 30: Recommended treatment plant for ground refuse

Table 24: Seasonal variations due to ground refuse addition
(See Table 23 for parameter definition)

Parameter	Summer	Fall	Winter	Spring	Annual Average
SBOD, mg/ℓ	112.25	118.92	108.32	112.95	113
NSS, mg/ℓ	1002.80	1354.00	794.97	1012.05	1041
TSS, mg/ℓ	1450.00	1850.00	1213.50	1542.30	1514
DBOD, mg/ℓ	112.12	133.00	100.26	114.58	115
GRIT, mg/ℓ	267.50	277.45	260.36	354.76	290
GSS, mg/ℓ	518.17	628.84	464.94	488.65	525
NSS, mg/ℓ	665.85	944.69	491.73	692.73	699

In order to evaluate the effect such a seasonal peak would have on the treatment plant operation, the computer model was run first with input parameters representative of fall alone, and then with the average values for summer, winter and spring. The results of this analysis indicate that some additional capacity would be needed to handle the increased sludge volumes, but that the major impact would be on secondary treatment facilities. It is estimated that the fall seasonal loading would result in a 44 percent increase in total solids and 20 percent increase in BOD entering the aeration basin. These increased concentrations would therefore require either increased aerator capacity or subsequent microscreening to provide equivalent removal efficiency. Microscreening affords the cheaper of the two alternatives ($2,000,000 as against $3,000,000 to increase the size of the aerator) and thus is included in our recommended treatment scheme.

Cost Analysis

As mentioned previously, the intent of this analysis is to provide a treatment scheme which could handle the higher concentrations of pollutants occasioned by ground domestic refuse, and yet not jeopardize the C classification of the Connecticut River at Bondi Island. The costs associated with such a proposal are necessarily a prime consideration in determining the feasibility of the wet systems concept.

According to the construction specifications of Springfield's consultants,[14] the Bondi Island plant will require a capital investment of $36,865,000. Our computer analysis provides a somewhat lower figure of $34,460,912. One reason for this discrepancy is that the computer program relies on national construction cost averaged to predict individual plant costs, yet at the present time, New England costs exceed the national average. Also, in the case of particular plant operations, the two cost figures may not describe identical processes. For example, the consultant's specification of sludge conditioning and filtration costs may include more than just wet air oxidation and vacuum filtration, which the computer uses to establish its cost figure. Moreover, it would be unreasonable to expect a program that is focussed on preliminary design to yield identical results with those of the final construction specifications. Table 25 provides a breakdown of the capital expenditure required for each process, both according to the consultant and the computer analysis. Using an interest rate of 6 percent and a 25 year amortization period, the capital cost would range between 11.50¢/1000 gallons (3¢/1000 ℓ) and 12.25¢/1000 gallons (3.25¢/1000 ℓ). Operation and maintenance costs are projected to be 5.8¢/1000 gallons (1.5¢/1000 ℓ), such that the total cost of treatment would be 17.3 to 18.05¢/1000 gallons (4.6 to 4.7¢/1000 ℓ) of sewage treated.

If the individual plant processes were to be kept as presently planned, but enlarged to handle ground refuse, the total treatment cost of these same facilities is estimated at 30.64¢/1000 gallons (8.04¢/1000 ℓ), or slightly less than twice the projected present cost for sewage alone. But, as mentioned previously, the introduction of ground domestic refuse would require modification of a number of plant processes, particularly those dealing with sludge handling, in order to avoid problems of clogging and inefficient operation. Therefore, it is more instructive to compare existing costs for sewage alone with those associated with the recommended wet-systems treatment scheme.

The initial capital cost of this modified treatment facility (Figure 30) is estimated at $49.4 million. Operation and maintenance would run in the neighborhood of 7¢/1000 gallons (1.85¢/1000 ℓ), such that the total treatment cost would be only 23¢/1000 gallons (6¢/1000 ℓ) or just more than 1.3 times the projected cost for sewage alone. The major cost savings would result from the replacement of the wet air oxidation unit with a conventional anaerobic digestion system. There was no provision in the cost analysis for income derived from methane gas production. Additionally, the computer model of the recommended treatment stream was run to simulate equivalent removal efficiency for a .4 percent by weight mixture of ground refuse in sewage, corresponding to a doubling in refuse generation rate to 3.58 lbs/cap/day (1.62 Kg/cap/day). Despite this increase, economies of scale result in an estimated cost increase of only 30 percent, to 29.9¢/1000 gallons (8.0¢/1000 ℓ). A summary of the cost data for treatment of ground refuse in sewage is provided in Table 26.

Conclusions

Our results for the cost of treatment of ground refuse-sewage mixtures are at first glance at considerable variance to those of Metcalf & Eddy.[15] If one excludes land acquisition and site preparation, our calculations show an increase in capital cost from $31.91 M to $42.63 M, or by a factor of 1.33; whereas Metcalf & Eddy anticipated an increase from $1.6 M to $4.1 M, or by a factor of 2.5.

Table 25: Treatment costs for sewage alone;
planned Bondi Island treatment plant

Item	Consultant's Estimated Project Cost	Computer Estimated Project Cost
Grit and screenings	$ 520,000	$ 127,270
Primary settling tanks	4,160,000	4,076,472
Secondary treatment facilities	12,630,000	11,177,441
Sludge pumping	650,000	352,833
Sludge conditioning and filtration	5,980,000	4,823,516
Sludge thickening	840,000	2,175,906
Chlorination	1,250,000	890,763
Electrical and Instrumentation	3,250,000	3,250,000*
Yard piping	2,600,000	2,600,000*
Site preparation	4,290,000	4,290,000*
Land acquisition and fees	695,000	696,711
TOTAL CAPITAL COST	$36,865,000	$34,460,912
	¢/1000 gallons	
TOTAL AMORTIZATION COST	12.25	11.50
TOTAL O & M COST	5.8	5.8
TOTAL TREATMENT COST	18.05	17.3

*Reproduced consultant's figures.

Table 26: Treatment costs for sewage containing ground domestic refuse

Item	Proposed Plant .2% Refuse	Recommended Plant .2% Refuse	Recommended Plant .4% Refuse
Grit & screenings	$ 128,225	$ 72,951	$ 84,026
Primary settling tanks	4,140,375	3,972,556	3,953,085
Secondary treatment facilities	16,906.792	15,764,124	20,940,392
Sludge pumping	551,872	885,936	1,159,230
Sludge conditioning & filtration	13,542,624	7,876,073	13,951,909
Sludge thickening	4,190,909	1,356,862	2,216,045
Chlorination	889,166	828,845	812,324
Microscreen	---	2,388,640	2,017,394
Electrical and Instrumentation	4,991,556	4,991,556	5,557.500
Yard piping	3,993,245	3,993,245	4,446,000
Site preparation	6,588,854	6,588,854	7,335,900
Land acquisition and fees	695,989	696,221	693,835
TOTAL CAPITAL COST	$56,619,607	$49,415,863	$63,167,640
		¢/1000 gallons	
TOTAL AMORTIZATION COST	18.84	16.0	21.10
TOTAL O & M COST	11.80	6.60	8.80
TOTAL TREATMENT COST	30.64	23.0	29.90

There are several explanations for this discrepancy. First, the Metcalf & Eddy estimates are for a facility of 1 mgd (3785 m^3/day) whereas our estimates are for a 64 mgd (242,240 m^3/day) facility. Second, the Metcalf & Eddy estimate was based on a refuse concentration of 0.5 percent by weight, whereas the projected concentration for Springfield is 0.2 percent by weight. Indeed, our calcualtion for an 0.4 percent by weight addition of refuse, corresponding to a 4.5 lb/cap/day (2.04 Kg/cap/day) generation rate, shows an increase of 1.72, which approaches the Metcalf & Eddy figure.

The approach taken in our analyses might perhaps be questioned on the basis that the use of design relationships based on sewage inputs are not necessarily valid for ground refuse additions. Whilst conceding that this may well be so, we have at least used a rational quantitative basis for our inferences and cost estimates, which, surely, must be preferable to intuitive qualitative judgments.

REFERENCES

CHAPTER V

1. For further details of this model, see Meier, P. and G. R. Fisette, "Modifications to the Executive Computer Program for Steady-State Simulation of Wastewater Treatment Facilities," Report by Curran Associates to EPA Solid Waste Research Laboratory, Cincinnati, Ohio, March 1974.

2. "City of Springfield, Massachusetts - Report on Sewage and Industrial Waste Disposal," Report by Camp, Dresser and McKee, Inc., 1971.

3. "Supplemental Study of the Connecticut River in Connection with the Proposed Bondi Island STP," Report by Camp, Dresser and McKee, Inc., 1971.

4. This model of the planned treatment facility is also discussed in detail in Meier and Fisette, *op. cit.*

5. Meier, P., J. Kuhner and C. J. Martel, "A Preliminary Assessment of Wet Systems for Residential Refuse Collection," Report by Curran Associates to EPA Solid Waste Research Laboratory, Cincinnati, Ohio, March 1974.

6. "Feasibility of Treating Sewage with Household Refuse," Report by Metcalf & Eddy to Foster-Miller Associates, Inc., 1971.

7. Kos, P., *et al.*, "Economic Analysis of the Processing and Disposal of Refuse Sludges," Report by Curran Associates to EPA Solid Waste Research Laboratory, Cincinnati, Ohio, March 1974.

8. *Ibid.*, Chapter IV.

9. *Ibid.*, Chapter III.

10. *Ibid.*, Chapter V.

11. *Ibid.*, Chapter IV.

12. Meier, *et al.*, *op. cit.*, Chapter IV.

13. The calculations assume the following average fractions of refuse categories to be ground: Paper 1.0; Garbage 1.0; Glass and Ceramics 1.0; Garden Waste 1.0; Wood 1.0; Plastics 0.9; Rubber, Leather and Textiles 0.8; Metal 0.3; Other 0.1.

14. "Contract and Specifications for Bondi Island Treatment Plant Construction," Report by Camp, Dresser and McKee, Inc., 1972.

15. Metcalf & Eddy, *op. cit.*, p.

CHAPTER VI

ENVIRONMENTAL IMPACT

Introduction

Although the environmental impact of a wet systems implementation was briefly considered in the introduction to the Phase I report,[1] a more detailed and specific analysis was deemed necessary as part of the case study evaluation. The emphasis in this chapter, therefore, is on the environmental impact of a wet systems implementation in the Springfield area, and drawing especially on the technical discussions of the preceding chapters.

The discussion is necessarily qualitative, rather than quantitative, and we have not attempted to attach dollar values to the environmental costs and benefits identified. And although the conclusion of the analysis is that the net impact will probably be beneficial there are one or two potentially serious impacts which cannot yet be assessed due to lack of data. Thus, even if accepted methodologies were available for the dollar measurement of intangible environmental impacts, inclusion of these dollar values into the engineering cost comparisons would be presently quite premature.

One of the difficulties in assessing the environmental impact of the wet systems concept is the need to assess the totality of environmental quality. Thus, air quality might improve at the same time that water quality might diminish, yet there is no accepted way to effect the tradeoff in even qualitative terms. Is one additional unit of BOD in a river worth the decrease of one unit of particulate emissions? Clearly, such questions can only be answered by reference to a specific situation and perspective, and the goals and priorities that govern the evaluation.

Air Quality

Air Pollution from Conventional Practice. There are two major potential sources of air pollution from conventional refuse collection and disposal practice: the emissions from collection trucks, significant especially in the central city, and emissions from incineration or illegal open burning in dumps.

With respect to emissions from collection trucks, the conditions under which they must operate make for very unfavorable emission conditions.

Internal combustion engines burn fuel most efficiently at relatively constant speeds, and the amount of unburned fuel increases sharply when a motor vehicle is accelerated or decelerated. Emissions of hydrocarbons, carbon monoxide and particulates may be 50 to 100 percent greater for average speeds less than 10 miles per hour (mph) as compared to

30 - 35 mph. This is illustrated on Figure 31, which shows how carbon monoxide emissions depend on mode of operation; and especially idling, acceleration and deceleration are associated with high emission levels. In central urban areas where distance traveled by collection trucks is slight compared to time spent, the contribution to urban air pollution from the collection fleet may be in excess of what it would appear to be if total miles traveled is used as a measure. For example, in the Springfield study area, the miles of travel by the 21 collection trucks may be conservatively estimated at 500 miles by map measurement. For each truck, the measured distance included length of the assigned route plus allowance for two trips to the landfill site. Since vehicular travel in Springfield amounts to over 1.1 million miles per day[2] this 500 miles is negligible. However, considering the substantial time spent idling and the fact that emissions during idling and speed changes may be greater than cruising emissions by factors of 2 to 6, the total contribution of the fleet to automobile air pollution may be on the order of 0.5 percent of the total.[3] In areas where collection truck traffic is dense or air movement is confined, the significance of this impact may be substantial.

Although neither refuse incineration nor open burning occurs in the Springfield area, the impact of such practices elsewhere is well recognized. The costs of municipal refuse incinerators are expected

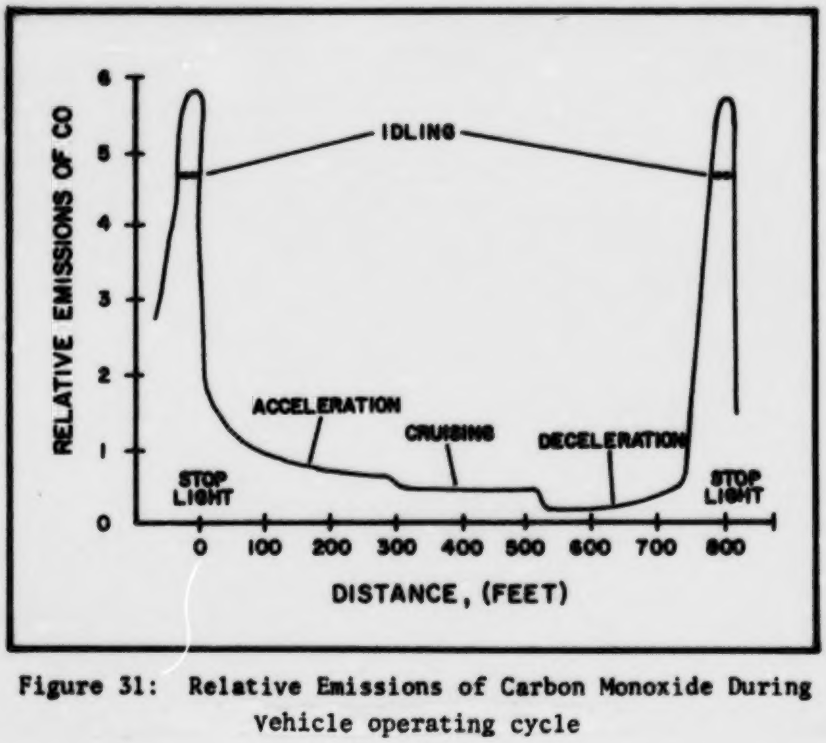

Figure 31: Relative Emissions of Carbon Monoxide During Vehicle operating cycle

by many to double as enforcement of emission standards becomes widespread,[4] and the impact of open burning was demonstrated all too tragically by a recent multiple car crash on the New Jersey turnpike reportedly caused by aggravation of fog conditions by smoke from a nearby dump.[5]

The Impact of Wet Systems on Air Pollution. Introduction of wet systems disposal for residential refuse would greatly decrease the number of refuse trucks on the streets. Collection by vehicle could be eliminated for all but those crews necessary to handle the nongrindable fraction of the refuse. Estimations discussed previously show that between three and four pickups per year will be required to handle nongrindables, requiring at most four collection trucks. Assuming identical unit emission levels would imply that air pollution from collection truck exhausts would be decreased 75 percent from present levels. A corresponding decrease should be experienced in support vehicle travel, such as vehicles operated by foremen and other supervisory personnel. On the other hand, it is expected that bulky item collections, currently involving two crews a day in Springfield, will require more vehicles for operations in conjunction with wet systems implementation, perhaps doubling in size.

Wet systems collection would virtually eliminate air pollution from on-site burning. The availability and ease of disposal of rubbish into the grinder should drastically decrease the incentive for onsite burning, making the enforcement of existing ordinances a more feasible proposition. But since it is primarily garden waste that continues to present incentives for on-site incineration in residential areas, the practical feasibility of having to carry such wastes into the house and to the basement grinder location is somewhat questionable. Nevertheless, immediate removal of such wastes by grinding may well offset this apparent inconvenience.

Because the wet system would landfill refuse in the form of sludge that may have 70 percent moisture or more, opportunities for open burning are clearly diminished relative to filling raw refuse. To the extent that the refuse sludge would be incinerated rather than landfilled, an additional source of pollutant emissions might be created; but there is no reason to assume that control of emissions at incinerators burning sludge is more difficult or costly than control at incinerators burning raw refuse.

Noise Quality

Noise from Conventional Refuse Collection Practices. Collection vehicles generate noise from the truck motor, the compaction mechanism and the crew during the loading process. Solid waste collection trucks travel their routes rarely at more than walking speed, and high sound levels are associated with both stopping, due to "sigh" of air brakes, and starting, due to revving the motor as the clutch is released. The truck motor must be revved during movement from stop to stop and during the compaction cycle. This produces a loud, low frequency sound of varying length in the first case, and of approximately 30 seconds duration in the second case, with sound levels of 90 dBA or higher depending on the type and condition of the truck. When the motor is engaged for compaction, a second source of sound is added to the motor noise. This comes from the compaction mechanism itself and sounds associated with the compression of loose rubbish. Although specific references are not available, it may be that higher estimates of noise production from collection operations found in the literature of 100-110 dBA may be associated with this peak output level.[6]

The noise resulting from the banging and clanging of the rubbish cans while being emptied may also be quite severe. This occurs not only when the collectors are carrying and emptying the containers, but also earlier in the morning when residents are bringing their cans to the curbside. Large steel drums tend to be more offensive since they are often too heavy for the collectors to lift and so are dragged out to the truck causing the high frequency rasping of metal against pavement. They are then banged against the hopper lip to assist in emptying. Less noise is produced if rubber, plastic or fiber containers are used instead of galvanized metal. Plastic and paper bags can be carried or dragged and loaded with little or no noise.

It should be pointed out, however, that the annoyance associated with a particular noise level is closely related to its duration, and thus the aforementioned impacts are not necessarily as great a nuisance as might be supposed. Nevertheless, a substantial proportion of complaints under newly introduced noise ordinances concern refuse collection,[7] and efforts are now underway for the promolgation and enforcement of federal noise emission standards for collection vehicles.

Observations in the Study Area. In the Springfield, Massachusetts, study area, several different trucks operated by the Division of Solid Waste, Department of Streets and Engineering were studied during our route surveys. One type of truck, a screw compactor model of German manufacture, was significantly different from all other models regarding noise level production. The compaction mechanism in this truck is a cylinder in which a corkscrew shaped blade turns continuously. Since compaction is continuous, the truck motor is constantly idling at a high rate. The blade gradually forces the waste material deeper into the cylinder, compacting the rubbish with new rubbish as it is loaded in. This continuous circular path of the rubbish against the corkscrew, cylinder walls, and a breaker blade in the truck causes a great deal of noise as the material is smashed and splintered into smaller pieces. Glass and metal pieces are notably noisy as they fall by force of gravity from the top of the cylinder.

Conversations with several Springfield residents living on routes serviced by the screw compactor trucks showed the people were aware of the increased noise from this type truck. One gentleman remarked that he had not complained because the truck was faster during loading than others and so the noise was of a more temporary nature.[8] This was a valid point since the collectors do not have to halt loading operations for a compaction cycle. This interview also verified the tendency of people noted earlier to discount disturbing noise if it is temporary. The majority of collection trucks in Springfield are rear loading hydraulic compactors of American manufacture, which are relatively quiet while idling. We observed that at every third stop a compaction cycle was necessary, at which time the truck motor is speeded up and the compaction mechanism is engaged. As noted above, the two loudest sources are thus operative simultaneously.

Impact of Wet Systems on Noise from Conventional Collection Vehicles. Since wet systems collection will require vehicular collection only of non-grindables, collection frequency will decline. With collection of refuse by vehicle decreased from once a week to an average of once every 16 weeks, the frequency of noise from collection vehicles would obviously decrease. In neighborhoods which may be near collection or disposal facilities, corresponding decreases in vehicle traffic could greatly lower the ambient noise level. Perhaps the most significant effect might be felt in dense urban areas where refuse collection contributes significantly to both noise levels and traffic congestion.

Wet systems will not of course affect noise levels when the trucks do collect in a neighborhood. In fact, because the frequency of collection would be much reduced, the presence of collection trucks might be much more noticeable.

Impact of the Wet System on Noise Levels in the Home. The major noise impact of the wet systems concept is that of increased noise levels in the home. But closer investigation reveals that even existing noise levels in the home are often high enough to be annoying. One writer was prompted to say that kitchen and household appliances are beginning to make the home as noisy as the factory.[9] Although noise is still not a required design consideration, more attention is being paid to the disturbing effects a noisy appliance may have on a home.

Noting the scarcity of reliable data available, the U.S. Environmental Protection Agency conducted measurements on 30 types of home appliances.[10] Sound levels were measured in dBA at a distance of 3 feet from the appliance installation and at a height of 5 feet. Figure 32 shows the measured mean of several representative appliances. For comparative purposes, the appliances were divided into four broad categories according to their noise levels.

1. Quiet major equipment appliances, characterized by operating levels lower than 60 dBA.

2. Quiet equipment and small appliances, characterized by noise levels between 60 and 70 dBA.

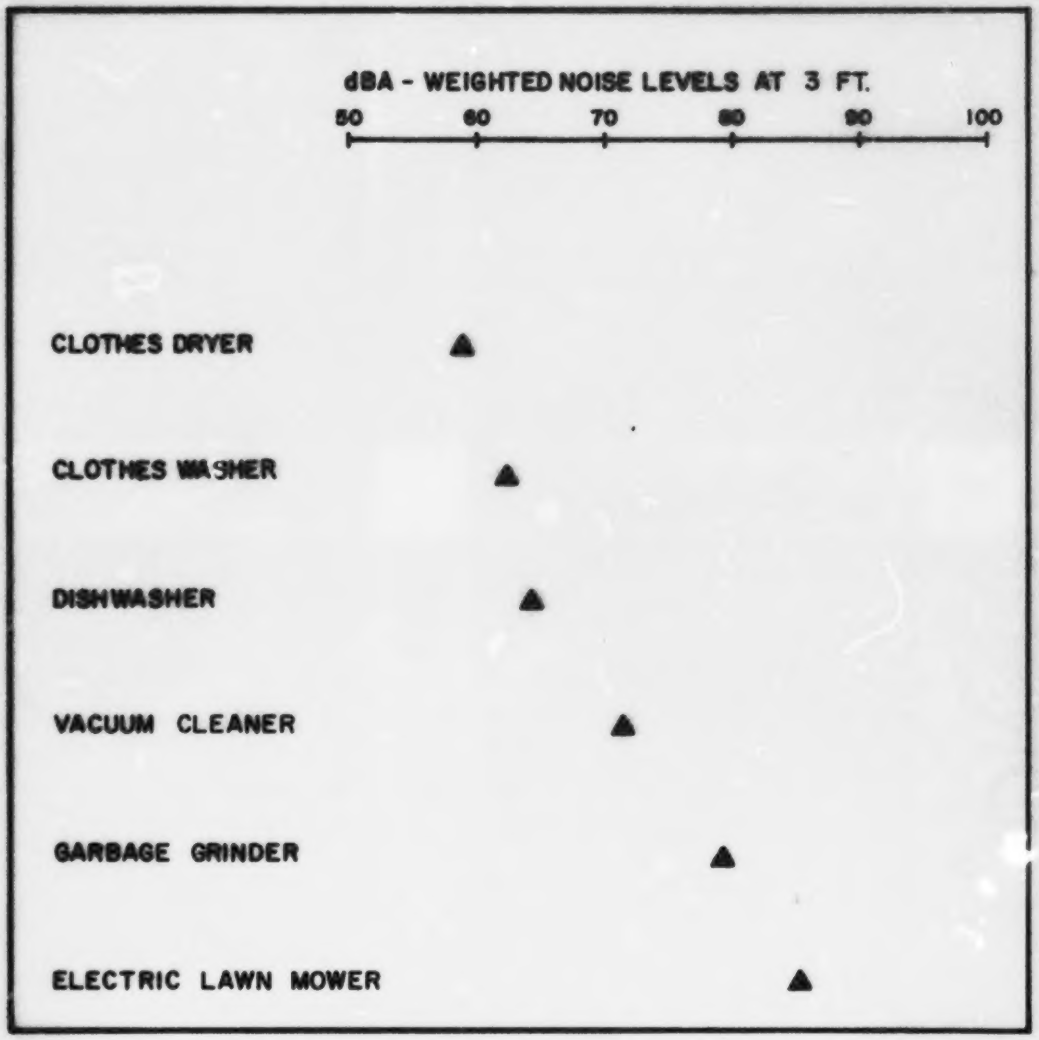

Figure 32: Noise levels of common home appliances

Source: Report to the President and Congress on Noise, U.S. EPA February 1972, pp. 2-118.

3. Noisy small appliances, characterized by noise levels between 70 and 80 dBA.

4. Noisy electric tools, characterized by noise levels in excess of 80 dBA.

These figures thus set the perspective for noise specifications for the refuse grinder.

The household refuse grinder designed by Foster-Miller incorporates several noise reduction features.[11] It is a wet process grinder which reduces noise from the tumbling of loose and flyaway pieces of refuse in the hopper. The grinder as designed is supported on an elastomer vibration isolation pad. Additionally, the hopper and top of the device are coated with a sound absorbing material to reduce grinding noise. In fact, noise levels might be less than from garbage grinders, since the latter has no lid to mask the grinding noise, and, for convenience of installation in sink, the motor and mountings may not be shrouded or mounted on dampers. Foster-Miller estimates their appliance as designed would be slightly more noisy in operation than a kitchen dishwasher,[12] with the noise levels estimated to lie in the range of 65-75 dBA. If this level of noise generation is accurate, the grinders would fall in either group 2 or 3 of the EPA appliance categories.

Since it is recommended the grinder be placed in the basement or other service area, the operator would be probably the only person receiving direct effects of the noise. The operator's exposure to the noise would most likely be infrequent and of brief duration. This moderates the relatively high noise level which might be encountered. The direct effects during operation would include speech interference; operators would probably avoid communication at this time, much the same as the operator of a vacuum cleaner presently does. But, if the actual noise level falls in the upper levels of the estimated range, hearing damage risk cannot be dismissed. Although the average exposure to such levels would be limited to fractions of hours per week, certain elements of the population might be subject to prolonged exposure. For instance, apartment maintenance men could be exposed to several hours of this noise daily. Although this exposure would not constitute an imminent hazard to hearing, it could nonetheless hasten eventual hearing damage in the context of cummulative exposure from many sources. However, unlike other noisy appliances, the operator for the grinder need not remain in the same room when the machine is grinding. Sound insulation afforded by moving to an adjacent room would reduce noise to acceptable levels.

Sleep interference would probably be minimal. In the household, operation times of the appliance could be arranged to avoid conflict with times persons are usually asleep. Due to service area or basement placement, noise levels from the grinder in bedrooms would probably be negligible.

Annoyance is probably the most significant of any indirect consequences. Operator annoyance is usually not as severe as annoyance to persons to whom the noise is intrusive. In single family homes, this effect is deemed slight since family members will have control over when the appliance is used. And as mentioned previously, frustration may not occur when the ability to stop or reduce intrusive noises is possible. Neighbors outside the single family home would not be exposed to significant noise levels due to shielding effects of the structure.

Noise standards for appliances are currently only a function of market place pressures. A survey of appliance manufacturers by the EPA showed that with the exception of air conditioners, there is little customer pressure for quieter appliances.[13] Indeed, sales of machines such as vacuum cleaners show strong demand for noisier machines; perhaps the American public equates power with noise.

In spite of the weakness of market pressure, many manufacturers do have research and development projects aimed at noise reduction. Most felt further reduction was possible with present technology, but that a 5 - 20 percent cost increase would be the penalty for quieter appliances.[14] It thus seems reasonable to conclude that noise from the refuse grinder, while noticeable, may not be serious. Provided they are of short duration, high noise levels are accepted by householders, and are not regarded as health hazards.

Public Health and Visual-Aesthetic Considerations

The impact of refuse collection practices on public health and on the visual-aesthetic environment are closely related, being both largely dependent on refuse storage methods preceding collection, and hence a simultaneous consideration of both elements is indicated. A wet systems implementation would largely eliminate the problems of storage of refuse awaiting collection, and a major beneficial impact on public health and the visual-aesthetic quality of the environment can be expected.

Storage Facilities. One study indicates that at least among low-income families, areas of multi-family dwellings may contribute less waste per capita than families in less dense, single-family structures,[15] and thus storage space required for each household may be greater in single-family neighborhoods. This will be offset to a large degree by the greater availability of places to store refuse in these areas. The typical occupant of a single-family detached home stores his refuse in trash cans, barrels, or bags. These are commonly placed outside the dwelling in a spot out of view such as the back or side of the structure. In row houses and apartment buildings, a central deposit area or receptacle is often provided. Location may vary from outside a parking lot to indoors in the basement of the building.

For both single-family and multiunit dwellings, storage locations can influence visual-aesthetic and public health impact. Outside storage relies on the refuse receptacle itself to hide the refuse, keep it from pests, and prevent litter and odor. An inside location, whether inside the dwelling, in the basement for example, or enclosed in an outside location, could compensate for inadequate containers. It should be noted, however, that insect and rodent vectors may not be impeded by any but the most secure enclosure.

All these methods are only adequate from the visual-aesthetic public health viewpoint if they are ideally used. A storage receptacle or facility should at minimum:

1. secure refuse and garbage from rodents, insects, dogs, and other vectors to prevent spreading disease;
2. keep unsightly waste completely from view to prevent visual intrusions;
3. retain odors inside the receptable;
4. avoid litter nuisances by preventing spillage during loading and collection and distribution of refuse by wind, rain, animals and people.

Observations in the Study Area. Although Springfield has adequate legislation to ensure proper refuse disposal, the ordinance is rarely enforced. The vast majority of containers placed on the curbside were inadequate in one or more of the four categories mentioned above. Predictably, these inadequacies were most notable in the poorer sections of the city, but present to a lesser degree in all sections.

In all but the most well-to-do suburban sections of the city, the majority of rubbish containers were not the standard 30-gallon galvanized trash cans with lids. Prevalent in numbers were plastic trash bags followed by galvanized 30-gallon cans without lids, then industrial metal drums of 40-55 gallon capacity, corrugated cardboard boxes, paper supermarket bags, pressed cardboard drums of 40-60 gallon capacity and finally standard 30 gallon cans with lids. No wet-strength paper bags made especially for refuse were observed.

The most popular storage methods in low income and redeveloped areas of the city observed are plastic bags, large metal and cardboard drums, paper supermarket bags and corrugated cardboard boxes, in that order. The plastic bag, often lauded for saving collectors' time, we found to be frequently misused. The abuses include stuffing the bag so full it tears, not tying the bag closed, and placing articles in the bag which puncture and tear the bag. These abuses, when they occur, render the bag useless in preventing litter, odor, pest breeding and feeding. The plastic bag properly used should be stored in a rodent and dog-free area since these creatures can easily make the food inside available by tearing the plastic. The plastic bag may retard animals somewhat by retaining odors which let the animals know food is near. However, bags stored habitually in the same place may not even be effective in this.

The large drums were found to have several disadvantages. They are not manufactured for rubbish and so have no lids, making their contents available to rodents, flies, and dogs. Litter is generated from these cans in another way. The cans are so large and often so heavy that they are tipped on their side and rolled by the collectors from curbside to the packer. This tipping often results in refuse being spilled out of the top of the drum since the drums are packed full to overflowing. The collectors seem to resent these drums and may not bother to pickup this spillage. As an alternate to tipping, the drums are often dragged to the truck. The cardboard containers develop holes in their bottoms from this, and are also susceptible to wetness from rain and wet garbage. The other two containers common in the low income areas, paper supermarket bags and cardboard boxes, are obviously deficient in all areas. Additionally, when wet from rain or garbage, these bags and boxes often rip when picked up, depositing their contents on the roadway or alley.

It is interesting that our survey teams noticed that the care taken in packaging the refuse at curbside was reflected in the care taken by the collectors in loading the refuse and in cleaning up spills and litter. Consequently, in areas where inadequate containers cause spills, where rubbish and garbage is dripped through wet paper sacks, torn bags, and tipped drums, collection crews are likely to leave the mess right where it falls. On spills which were their own fault, the collectors were usually diligent in cleaning up their mistakes.

The above phenomena may have a correlation with individual pride. In the single family neighborhood, more space is available for placement of refuse for pickup. A messy, untidy pile of rubbish is identified with the home owner. In multidwelling units where less space is present, unsightly communal storage areas do not reflect as directly on an individual occupant, hence the individual's sense of responsibility is absent.[16]

Cross Connections. Perhaps the most serious potential public health impact, and the one that would certainly attract close attention from public health authorities, is the possiblity of a faulty cross connection in the grinder.[17] This possibility exists because of the need to provide freshwater for the flushing cycle that must follow grinding.[18] Cross connections are a recognized public health hazard, and major epidemics of water borne diseases in the developed countries almost invariably follow the incursion of wastewater into the water distribution system via some form of cross connection.

However, it could be argued that the stringent laws and regulations concerning cross connections were developed of necessity in a time when water and wastewater systems were introduced to urban areas haphazardly, and without adequate supervision. But if the grinder is designed in such a way as to inherently avoid possible hazards, the anticipated fears of the public health authorities might well be allayed. The engineering principles of cross connection control are well understood,[19] and no insurmountable difficulties are anticipated in adhering to these in the design of refuse grinders.

Impact on Rodent Control. As all putrescible components of refuse would be quickly disposed of through the grinder, no burden is placed on the householder to safeguard the refuse or garbage against vector infestation. Refuse would, in the storage and collection phases, virtually be eliminated as a source of food for rodents and insects, with the possible exception of rodent populations in the sewers. It is conceivable that the rodent problem in sewers might be increased if more food in the form of ground garbage and food waste was delivered to the sewers. Evidence has been offered to support the fact that a high density of garbage grinders in a community may be associated with increased rodent populations.[20] This relationship is uncertain, however, because rodents commonly reside in sewers, even when food sources are on the outside. In the study area, serious rat problems occur in areas of combined storm and sanitary sewers, rather than in the areas where garbage grinders are prevalent. Indeed, there is evidence that domestic sewage without ground refuse may be capable of supporting rat populations. The Building Research Advisory Board of the National Academy of Sciences feels that grinding garbage for disposal to sewers offers a net benefit to control of a communities rat population.[21] And since it is known that shredded raw refuse in landfills is not suitable for rodent consumption, one can only surmize that mixed refuse suspended in water would be even less suitable.

The elimination of curbside refuse storage has some further unexpected and beneficial consequences. For example, a recent study linked urban stray dogs to the urban solid waste problem[22] and established the free-running urban dog as a part of the cycle of urban waste, litter, and disease. It was found that the dogs may exist in a symbiotic relationship with urban rats. The dogs often assist the rats unknowingly by tearing bags and spilling trash cans in their own search for food, and were observed feeding on refuse side by side with rats. To the extent that this food source would be eliminated, a wet systems implementation might play a substantial role in the control of the stray dog population, a problem that is becoming to be recognized as very serious.

Resource Recovery

Springfield is involved in a multifaceted recycling and recovery program in conjunction with its present conventional solid waste collection and disposal system. Recovery of newspapers, bulk metal, garbage and digester gas are the major items in this program.

Newspaper. Newspapers which the household has segragated from other refuse and tied into bundles are put into separate racks under the collection trucks by the crew on their regular weekly pickup. At the landfill, the accumulated newspapers are loaded into a scrap paper dealer's truck. The newsprint is transported by the scrap dealer to his nearby plant for shredding and baling.

The scrap dealer pays the city in accordance with the current market rate for old newsprint. In 1972, 648 tons of newspaper was recovered yielding a revenue to the city of six dollars per ton. Additionally, salvage dealers who are authorized and licensed by the city to collect old newspaper gathered 127.71 tons of newsprint. Calculations based on estimates of the percentage of newspaper in municipal waste[23,24] indicate the total weight separately collected by private and municipal forces may be roughly 20 percent of the total newspaper discarded in Springfield.

The paper scrap dealer-broker servicing Springfield has a large delivery network to both integrated and independent paper mills. At present, due to a severe pulp shortage caused by logging strikes affecting Canadian lumber production, flooding in the southern United States and hence an increased paper demand, this paper dealer could sell much more waste paper of all grades than he is presently receiving. Most of his scrap input is obtained through arrangements with private firms for their waste. Supermarkets and department stores, for example, will deliver corrugated paper, counting saved landfill charges as partial or full payment. Besides the small volume of scrap currently flowing from municipal waste, the flow shows seasonal variation, decreasing in the winter and increasing in the spring and summer. Contracts for deliveries which both the dealer and mills prefer are difficult for the scrap dealer to comply with if his input is irregular. Negotiations are currently ongoing between the scrap dealer and the city to formulate a joint effort for increasing both volume and dependability of waste paper flow.

Bulk Metal. Bulk metal items are collected on appointment in Springfield. Specific crews equipped with open trucks collected and delivered to a local scrap dealer 866.22 tons of light metal in 1972. The scrapper compresses and bales the scrap as No. 3 or "Brooklyn" bundles reflecting their high impurity content. The scrap dealer does not pay the city for these items. Nonmetal bulk items were also collected, but were discarded at the Bondi Island landfill site. Total requests for bulk item collection in 1972 numbered 10,056.

Assuming total metal comprises roughly 13 percent by weight of municipal refuse,[25] it may be calculated that roughly 9 percent of the metal in Springfield municipal refuse was recovered through bulky metal item collection. We estimate from our observations that less then half of bulky metal items are presently recovered in Springfield.

Garbage. Presently, garbage is collected by separate collection forces in Springfield. In 1972, 3,286.1 tons of mixed garbage was collected and sold to Marten Bros. Piggery. The garbage is loaded onto a trailer at Bondi Island for transportation to the piggery at Auburn, Massachusetts.

It is known that most garbage in Springfield is either included in refuse for collection or disposed of through garbage grinding. In his yearly report for 1972, the Deputy Superintendent of the Division of Solid Wastes for the city recommended that separate garbage collection be abolished. It seems merely a matter of time until this is the case. Rough calculations using the main component of garbage, food waste, as 18.6 percent of total refuse, show that garbage collected and sent to the piggery may amount to only 23 percent of the total actually generated.

Digester Gas. The gas produced by the digesters at the existing wastewater treatment facility is utilized to heat the digester and treatment plant buildings. It also fuels a generator which provides electricity for the treatment plant operation. The digester gas is recovered from the tanks and stored in a large steel sphere. From the sphere, the gas is either used or wasted to the atmosphere. In the recent past, the gas was also used to heat the maintenance garage used for solid waste collection vehicles. This practice has been discontinued, possibly because of an unreliable flow of gas especially in the winter months. Data from 1972 show that approximately 53 percent of the digester gas was utilized, the rest was wasted.

Further Opportunities for Recovery Under Conventional Systems. Conventional solid waste handling schemes such as Springfield's were not designed to promote resource recovery, and substantial additional efforts will be necessary to create opportunities for recovery within the framework of the present system. New technology for solid waste collection and disposal may offer other opportunities. Separation operations such as the Sortex Company's glass sorting system may be amenable additions to a conventional system. Two other schemes, the Black-Clawson and the Bureau of Mines systems potentially offer opportunities for simultaneously reclaiming a variety of materials. The reader is referred to the Phase I evaluation of these systems for further technical details.[26] In a survey of 944 communities with populations of 10,000, Darnay and Franklin[27] found that 94 percent of the communities had no recovery programs, while only 6 percent did. Of those who did not recover, 11 percent at some time had a program but dropped it for various reasons. Of those who did have programs, Table 27 shows the percentage of communities which recovered various wastes.

Of these cities, 25 percent had recovery programs involving separate collection of recoverable items only, 58 percent involved separation at the landfill only, 8 percent at an incinerator only, and 4 percent each involving separate collection in conjunction with separation at a landfill in one case and at an incinerator in the other.

The results of this survey indicate that Springfield is clearly among the more advanced cities in regard to recovery. No information in the

Table 27: Percentage of 24 communities which recover various wastes

Waste	% Cities with Recovery
Paper	49%
Iron/Steel	28%
Other Metals	1%
Glass/Ceramics	2%
Plastic/Rubber	0%
Textiles	0%
Organics	20%

Source: Darnay and Franklin, op. cit., p. 154

survey is given indicating effectiveness of recovery programs where they do exist. Springfield, with its separate collection for recoverable items, relies on citizen effort to segregate the refuse as it leaves the household. Calculations previously discussed indicate that very low percentages of the materials available are recovered, presumably due to lack of participation by the householder.

However, some other alternatives that do not involve householder cooperation are under consideration, in particular the use of municipal refuse as a supplementary fuel in coal fired power utility boilers. A project similar to the pilot study presently ongoing in St. Louis, Missouri, was proposed to Springfield by the Western Massachusetts Electric Company.[28] The West Springfield Electric Generating Station is adjacent to the Bondi Island sanitary landfill site. Shredded municipal refuse with ferrous metals removed would be used as a small percentage (10-20 percent) of the fuel to the plant boilers. To date, no action has been taken on this invitation.

Also involving the West Springfield Generating Station is a possibility of using fly ash from the boilers as fill material for the nearby sanitary landfill.[29] Although it is not presently occurring, it has been done in the past and may resume if details of the transactions could be agreed on. (See also Chapter III, above.)

Impact of a Wet Systems Implementation. The impact of a wet systems implementation on resource recovery efforts is especially difficult to predict in view of the uncertainties surrounding the markets for recycled products. The plans for a statewide resource recovery system were reviewed in Chapter III, above, and few specifics are yet available. Study of the problem shows, however, that a wet system implementation would little affect whatever measures might be proposed under conventional concepts. A general analysis of the probable impact on resource recovery has already been developed in Phase I,[30] and we shall therefore restrict ourselves to a brief consideration of the impact on the resource recovery efforts presently underway in Springfield.

As shown in Chapter III, only a small portion of Springfield's garbage is currently delivered to a local piggery, and the separate garbage collection is planned to be eliminated. Under the wet system, the garbage fraction of refuse would find its way to the wastewater treatment facility, and, if anaerobic digestion is practiced, provide a substantial portion of the volatile solids that are converted to methane. This would seem preferable from a resource recovery viewpoint over the direct landfilling that is currently planned.

With regard to newspaper recovery, it would appear that the feasibility of segregation by the homeowner prior to grinding under a wet system would be no different to segregation under conventional practice. Segregated newspaper could be picked up at the same time as the non-grindables, just as it is today by the regular collection. Ferrous metals, too, could continue to be recovered as at present. However, the amounts of metal deliverable to the scrap dealer would be substantially higher, as not only bulk metal items, but also the non-grindables, a major fraction of which would be metal, could be readily recoverable at very low cost.

One area of resource recovery that would be substantially affected is that of burning shredded raw refuse at the Western Mass. Electric utility boilers as a supplementary fuel. It could be argued that suitably dried (undigested) sludge might also be used as such a fuel, with the advantage that no metals or abrasive components would be present, and that no shredding would be necessary. However, raw refuse is often quoted as having a heat value of about 6,000 Btu/lb, whereas the ground refuse sludge might have a heat value of 7,300 Btu/lb dry solids or about 2,200 Btu/lb of total sludge at a 30 percent solids content.[31] From the utility viewpoint, this would therefore represent a rather poor fuel, and the prospects of disposing of sludge by this route would appear to be somewhat dim.

Water Quality

The impact of a wet systems implementation on water quality in the Springfield area must be put in the context of existing shortcomings in water quality management in the region. Three areas are currently of concern; the landfill at Bondi Island, the discharge of stormwater overflows into the Connecticut, and the inadequacies of the existing primary wastewater treatment facility. Only in the last area are current plans sufficient, and the new planned secondary treatment facility is about to enter construction.

The refuse disposal site currently used in the study area is regarded by many as a threat to surface and ground water supplies. Located on

Bondi Island in the town of Agawam, Massachusetts, adjacent to the Westfield and Connecticut Rivers, most of the site is a flood plain that includes a post-glacial oxbow pond. As noted in the C. E. Maguire report,[32]

> Groundwater is at or near the ground surface throughout the site... Geological limitations for use of this site include the high ground water level and flood hazards.

Recommendations to close this facility must be put in the light of the realities of the fragmented New England governmental structure, and the exceptional difficulty of finding politically acceptable sites.

In Springfield, combined sewers still serve the downtown and surrounding older sections of the city while newer suburbs have separate systems, as indicated on Figure 14. The impact of storm water over flows on the water quality of the Connecticut River below Springfield is substantial. Presently, a two month frequency storm of 30 minutes duration results in the carrying of 10 tons of BOD into the river.[33] Significant reduction of dissolved oxygen levels in the river results, although the depletion is not sufficient to violate the Massachusetts' C water classification of the Connecticut River. Present plans to alleviate this situation were outlined in Chapter IV, above.

Impact of Wet Systems on Water Quality. Although recognizing the limitations of the computer model and its results as discussed in Chapter V, we do not foresee any difficulty in meeting the same effluent quality with ground refuse as is foreseen for the new planned facility, and the water quality of the Connecticut River, as measured by conventional parameters, would not be compromised. Indeed, to the extent that the Bondi Island landfill site, which might be unsatisfactory from a water quality viewpoint, would be used for landfilling of a stabilized digested sludge containing no free moisture rather than for filling of raw refuse, the net impact on water quality would be positive.

With regard to the combined sewer overflows, we have already noted that the implementation of a wet system in Springfield would be contingent on a prior or simultaneous separation of combined sewers. But since we anticipate that grinders would first be installed in the relatively affluent suburbs,[34] all that would need replacement initially are any combined interceptors that carry wastewater from outlying areas through the central areas where combined sewers are prevalent. This would avoid any additional storm water loads on the Connecticut River resulting from ground refuse additions.

Need for Revised Effluent Standards. In view of the rather limited information on the possible quality of effluents from wastewater treatment facilities handling ground refuse, the need for revised effluent standards is difficult to ascertain. Metcalf and Eddy's experiments do show, however, that the COD of conventional secondary effluent would be substantially higher than present levels, due mainly to fine cellulose fibers in suspension. A standard for COD would therefore be indicated for such facilities, although establishment of the permissible levels would need further bench and pilot scale studies. As indicated by our computer model results, there appears to be little difficulty in meeting existing effluent quality limitations for BOD, suspended solids, dissolved nutrients or other parameters commonly in use for sewage treatment effluents.

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CHAPTER VI

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CHAPTER VII

SOCIOECONOMIC ANALYSIS: FUTURE TRENDS IN RESOURCE COSTS

Introduction

In this chapter, we shall explore the basic premise that the costs of conventional handling of solid waste will rise rapidly in the future and make alternative methods more attractive. We discuss the real costs of resources in turn: labor, capital, land, and environmental costs; where environmental costs are regarded in terms of a degradation of environmental resources. The focus is on likely future trends in costs, in order to test the main thrust of the argument that conventional methods will become increasingly costly.

The detail here is all too often qualitative rather than quantitative, partly due to the lack of past data on which to base projections, partly on the fact that many factors relevant to future projections are impossible to predict with confidence, either because we have no past experience which is relevant or because we cannot assume the past experience to continue to be relevant. We have attempted to uncover evidence which would improve the 1988 total cost comparisons between conventional and wet systems methods developed in Phase I of the project. Even if that comparison cannot be made with as much precision as we would like, the qualitative discussion here should be useful in guiding further research.

As suggested in Phase I report, there are a number of economic reasons for re-examining the desirability of conventional collection and disposal of household waste for considering radically new methods, such as wet systems methods.

In one way or another, all the alleged shortcomings of conventional methods are really aspects of a single problem: the real costs of conventional handling seem likely to increase rapidly in the future, if it is done in ways which minimize environmental damage. Cost increases are considered likely because:

1. Conventional methods draw heavily on particular resources which are and will be scarce and valued highly, either in the market place, or in the decision-making calculus of households, or in public opinion.

2. In the long run, the very nature of conventional methods will limit cost savings through substitution of cheaper resources for the valuable ones.

This statement of the problem implies that "resources" should be interpreted widely, more widely than those resources bought and sold in the market place. They should include all human labor, whether paid a wage or not, as well as environmental resources. Such a wide interpretation of resources is necessary for our purposes, because we are assessing the total socioeconomic impact of different methods, not just the monetary costs to governments and households. Economic analysis calls for a wide interpretation of resources, and especially environmental resources have been prominent in modern cost-benefit analysis. The real value of time and unpaid labor of individuals has also been stressed in assessing transportation planning (valuation of savings of travel time) and education (opportunity cost of students' time). The appropriate valuation of leisure time has also been discussed in recent analyses of the extent to which economic growth has produced genuine increases in living standards.[1]

What we mean by "conventional methods" is reasonably clear from earlier discussion. In the present context, they mean all activities in handling household waste which could be substituted for by wet systems. That means they are limited to methods for handling grindables. However, they refer to more than merely the collection of waste by paid forces; they also include the handling of waste by household members--the movement of containers from house to curb, and transportation of waste to landfill by households who do not or cannot use paid collection--if sewers make wet systems technically possible. In other words, we include under "conventional" the handling of waste from households which are sewered, but not served by paid collection forces.

If we interpret resources widely, the resources absorbed in conventional collection and disposal are: Paid labor by employees of governments and private collection and disposal firms; unpaid "household labor;" capital equipment, such as collection vehicles, disposal equipment, garages; land, chiefly in disposal sites; and, environmental resources, such as clean air and water, quiet streets, general absence of disease vectors, etc. All of these will be discussed in the following sections.

As in the Phase I report, we here concentrate not on the absolute magnitude of future cost increases, but on increases relative to increases in prices in general. A review of some selected indices may be relevant at this point; for example, the Consumer Price Index increased at an average annual rate of 2.5 percent between 1947 and 1972, 3.3 percent between 1962 and 1972, and 4.6 percent between 1967 and 1972.[2]

Another widely used index is the "GNP Deflator." It covers the entire range of goods and services in the economy, not just retail consumer prices as the Consumer Price Index does. However, it is recognized as deficient because it records the "price" of government employees' labor as exactly equal to their wage rates, with no allowance for any increased productivity. Therefore, we chose the index excluding general government services (what is given here does include prices of goods and services purchased by government from private industry); the average annual increases are: 2.4 percent between 1947 and 1972, 2.9 percent between 1962 and 1972, and 4.0 percent between 1967 and 1972.[3]

Labor

Conventional collection and disposal is highly labor intensive. The Phase I report refers to data showing labor costs at 70-80 percent of total money costs. The Springfield cost reports for 1972 estimate labor costs at 62 percent of the total with no allowance for fringe benefits. Fringe benefits are around 20 percent of wages, so the labor cost fraction would use up to about 67 percent of total cost including fringe benefits. We suggest later that unpaid household labor is also important quantitatively; when valued at an opportunity cost which is plausible, although well below market wages, the value is not at all insignificant relative to paid labor costs.

The Role of Unit Labor Costs. The "unit labor cost" is the total labor cost necessary to produce one standardized unit of output--for example, the collection of one ton of rubbish from a given neighborhood. Changes in unit labor cost depend on the changes in the wage rate per hour and the changes in the number of man-hours required to produce one unit. To be specific, the percentage change in unit labor cost is the percentage increase in the hourly wage minus the percentage decrease in the number of man hours required, or, more commonly, the percentage change in the hourly wage minus the percentage increase in "productivity," measured by output per-man hour.[4]

While the wages of labor do not rise at the same rate in all industries, there are pervasive general forces which combine to raise most wages fairly steadily over time, at a rate faster than the rate of inflation. For example, between 1947 and 1972, the average hourly wage in the United States (private economy only) rose by 291 percent, or an average of about 5.5 percent per year, including fringe benefits, while the consumer price index increased only 87 percent, or an average of 2.5 percent per year.[5] Thus the "real wage" (the money wage rate adjusted for purchasing power) rose steadily at 3 percent per year between 1947 and 1972. The major forces in this are the same ones which are chiefly responsible for continued economic growth; they are ones which increase the productivity of labor in large parts of the economy, due to greater education and training of workers, the use of more and more capital per worker, and the general advance of knowledge. These pervasive forces raise the productivity of labor in most industries, which can afford to pay and do pay higher wages in the market place. Thus wages tend to rise to some degree for all industries; any given industry finds the wages it must pay somewhat beyond its control, and it must pay higher wages even if its own labor productivity does not increase as fast as in the typical industry.

Of course, there are other forces operating on the wages of an industry, forces more peculiar to it alone. These include the attractiveness of its working conditions, extent and nature of union activity, and the abundance of labor with the necessary skills. These forces will accentuate the increase of wages caused by economic growth in some cases. In other cases, they will moderate the increase. It is extremely rare, however, for them to slow the growth of wages to zero or to produce an actual decline in them. The contrary examples are for isolated cases and for only temporary periods, and may be ignored in considering a general theoretical framework.

Given the increase in wage rates, it is the increase in worker productivity which will determine how fast unit labor costs grow. Industries vary widely in their ability to increase productivity. Some industries exhibit rapid increases in productivity--manufacturing, agriculture, transportation and public utility operations are major examples. Standardized products, mechanization, large scale production, and automation are possible. Others, particularly those producing services, have shown much slower increases. They are cases where a large amount of time-consuming labor is necessary to produce the service at all, and mechanization may be out of the question. Many of them have no special forces moderating increases in their wage rates, so the net result is an increase in their unit labor costs relative to other industries. And the increase in labor cost will usually lead to an increase in relative price, especially where labor costs are such a high proportion of the total in the first place.

In the face of rapidly rising unit costs for these products, society can respond in several different ways. High prices may turn consumers and other buyers away--the product is simply "priced out of the market." This is especially likely if cheap substitutes are available. A prime example is personal maid and valet service, which a century ago was a service widely consumed even by the middle classes, but which has been drastically reduced by its high price and the availability of labor-saving household appliances. Handcrafted items, including decorations on buildings, are other examples. They are no longer competitive in price, and people "cannot afford" them, even though they regard them as "better" in some absolute sense and openly regret that they can no longer be found at a reasonable price.

One of the activities whose relative cost has risen is leisure time activity. Almost by definition, leisure time is labor intensive, and the true cost of such time is measured by opportunity cost: the wages foregone by sacrificing work for leisure. Many claim the increasing opportunity cost of leisure accounts for much of the hectic pace of modern life, and say people "don't take the time" to do things as they used to. On the other hand, it is clear that consumer preferences for certain kinds of leisure time activities are very strong, and they are heavily in demand despite the rise in opportunity cost (one reason is that other inputs, such as recreational equipment and long distance transportation, are getting less expensive). Nevertheless, the trend of rising real wage rates calls for an increasing real cost to be assigned to household labor in various tasks, whether it comes at the expense of work or leisure.

Even with this higher real cost, however, many persons have substituted their own household labor for paid labor, the monetary cost of which seems to be regarded as an even higher cost: automobile driving for work and pleasure and home handiwork and repair are examples, having been substituted for public transportation and paid repair labor, respectively.

A number of economic theorists have emphasized the importance of the general framework described above in understanding the patterns of growth in an advanced society. Scitovsky and Scitovsky[6] referred to the high cost of labor as one of two features of the advanced economy with important cultural and social implications (the other being large-scale organization and extreme specialization), and elaborated on some of the results in terms of distribution of leisure; the diversion of time from intellectual and cultural activities and genuine leisure towards unpaid household labor in the home; the hurried pace of leisure activities; and the reluctance to spend the amounts required to maintain the quality of public transportation and other public services in spite of their higher costs. And Linder[7] wrote a lively account of the hectic pace of modern life and people's tendency to cram too much into their leisure time in his The Harried Leisure Class.

Many other goods and services survive and flourish in spite of their expense, however, because consumer and public tastes show very strong preferences for them. The demand for some of them is very income elastic, so that preferences for them become all the stronger as incomes rise. The higher incomes resulting from economic growth turn out to change tastes enough to offset the higher wage rates which the same growth also produces. Examples are education and medical care, which are highly labor intensive, but which have continued in strong demand. Consumers and governments have been willing to pay the inevitable higher prices and divert more and more total expenditures to their purchase. Thus, wage increases and productivity changes largely determine whether the relative price of a good or service will rise or fall, but the forces of demand determine whether the relative price change will greatly reduce the quantity produced.

Baumol[8] argued that the differential rise in unit labor costs was one of those "economic forces so powerful that they constantly break through all barriers erected for their suppression," and was crucial to understanding the "anatomy of urban crisis." He found it instructive as a first approximation to divide economic activities into two groups: technologically progressive ones, and others which permit only sporadic increases in productivity. The basic differentiation is the role of labor. The first is a group of activities in which labor is primarily an instrument, while the second is a group of services in which the labor itself is the end product. Assuming that wages in both sectors rise as rapidly as output per man hour in the progressive sector, the result is an inevitable increase in the relative cost of the second group of activities. Baumol notes as examples of this group the following activities, usually financed privately: retailing services, fine pottery and glassware, fine restaurants, live performance of music and drama, some medical care. But many other examples are financed publicly, especially by cities, and they explain some of the mounting fiscal pressures on municipal governments: "A critical element in the explanation becomes clear when we recognize how large a proportion of the services provided by the city are activities falling in the relatively nonprogressive sector of the economy. The bulk of our municipal expenditures is devoted to education which... offers very limited scope for cumulative increases in productivity. The same is true of police, of hospitals, of social services, and of a variety of inspection services. Despite the use of the computer in medicine and in traffic planning, despite the use of closed circuit television and a variety of other devices, there is no substitute for the personal attention of a physician or the presence of a police patrol in a crime-ridden neighborhood. The bulk of municipal services is, in fact, of this general stamp..."[9]

Empirical Data. Unfortunately, there are no good data with which to test how well solid waste management fits into this general framework. We do know that state and local government expenditures on all functions together have grown much faster in the postwar period than other national aggregates, such as Gross National Product or private consumption. Expenditures by local governments for solid waste management are typical in this respect (see below). However, the theory would hold only for total resource cost, trends which may not be well measured by trends in money expenditures in the public sector. The public expenditures exclude household labor; they exclude the resources employed in private collection and disposal firms who sell their services directly to households; they include capital expenditures all at once in the year they are made, rather than amortizing them over the lifetime of assets. The true opportunity cost of land used for disposal is not reflected either, if the land was bought in earlier times and later made available for disposal. In addition, the theory applies to costs of service at a given constant quality level, and we cannot know whether quality has been kept constant over any given time span.

However, the data on public expenditures are all that are available, and a sample has been assembled in Table 28 showing levels and trends in per capita expenditures on solid waste collection and disposal (including street cleaning), as compared to total public expenditures. The figures include payments to private firms collecting under contract with municipalities. The data are for the years 1962 and 1967, when extensive data were collected as part of the Census of Governments, and 1971, the latest year for which similar data are available. The table compares solid waste expenditures by governments to total expenditures for all functions and also for all functions excluding education and public welfare. Education spending is affected by demographic trends inherited from past birth rates and by the rapid expansion of public higher education in the 1960's. In welfare, there have been sharp shifts in responsibility from local to state governments, which would affect the trends for local governments alone. We have also included data for sewerage expenditures in light of the specific point of this report. In all cases, local government spending includes that financed by state and federal grants. The table includes data for the nation as a whole and for large metropolitan areas as a group. In view of the focus of this report on the Springfield

Table 28: State and local government expenditures per capita for various functions, fiscal years 1962, 1967, 1971[a]

Type of Government and Expenditure	Amounts 1962	Amounts 1967	Amounts 1971	Annual Rates of Change, percent 1962-67	Annual Rates of Change, percent 1967-71	Annual Rates of Change, percent 1962-71 (avg.)
Gross National Product per capita (for comparison)	$3,004	$3,995	$5,073	5.9	6.2	6.0
All U.S. State and Local Govts.[b]						
Total Expenditure	324	472	731	7.8	11.6	9.5
-exc. Education	204	280	442	6.5	12.1	9.0
-exc. Education and Public Welfare	177	239	354	6.2	10.3	8.0
All U.S. Local Governments[c]						
Total Expenditure	214	299	457	6.9	11.2	8.8
-exc. Education	118	154	245	5.5	12.3	8.5
-exc. Education and Public Welfare	104	135	208	5.4	11.4	8.0
Solid Waste[d]	3.69	4.49	6.98	4.0	11.7	7.3
Severage	6.85	8.26	12.82	3.8	11.6	7.2
Local Govts. in 72 Large Metropolitan Areas						
Total Expenditure	NA	347	546	NA	12.0	NA
-exc. Education	NA	194	318	NA	13.2	NA
-exc. Education and Public Welfare	NA	166	262	NA	12.1	NA
Solid Waste[d]	NA	6.33	9.85	NA	11.7	NA
Severage	NA	10.42	16.45	NA	12.1	NA
All Local Govts. in Massachusetts						
Total Expenditure	247	328	424	5.8	6.6	6.2
-exc. Education	154	202	229	5.6	3.2	4.5
-exc. Education and Public Welfare	119	153	219	5.2	9.4	7.0
Solid Waste[d]	4.56	5.40	7.98	3.4	10.3	6.4
Severage	5.38	5.48	11.26	.4	19.7	8.6
Local Govts. in Hampden and Hampshire Counties, Massachusetts[e,f]						
Total Expenditure	239	277	353	3.0	6.3	4.4
-exc. Education	145	158	182	1.7	3.6	2.6
-exc. Education and Public Welfare	118	120	172	.3	9.4	4.3
Solid Waste[d]	3.54	4.05	5.48	2.7	7.9	5.0
Severage (exc. capital outlay)[g]	1.62	1.97	4.45	4.0	22.6	11.9
City of Springfield[f]						
Total Expenditure	252	315	391	4.6	5.6	5.0
-exc. Education	175	215	230	4.2	1.7	3.1
-exc. Education and Public Welfare	130	158	222	4.0	8.9	6.1
Solid Waste[d]	5.05	6.25	7.49	4.4	4.6	4.5
Severage (exc. capital outlay)	1.88	2.62	7.02	6.9	27.9	15.8

Sources: The Gross National Product data are from *Economic Report of the President*, 1973. All other data are from various volumes of U.S. Bureau of the Census, *Census of Governments*, 1962 and 1967 (for 1967, Vol. IV, No. 5, *Compendium of Government Finances*, and Vol. VII, No. 21, *State Reports: Massachusetts*; for 1962, the same reports which were Vol. IV, No. 4 and Vol. VII No. 21, respectively), and these annual reports of the Bureau: *Governmental Finances in 1970-71*, *City Government Finances in 1970-71*, and *Local Government Finances in Selected Metropolitan Areas and Large Counties: 1970-71*.

Footnotes to Table 28:

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[a] All expenditure data are for what are called "direct general expenditures" by the census. They include capital and noncapital outlay for all functions except liquor stores, government utilities (water, electric, gas and transit), and retirement and other insurance trust funds. Neither employer contributions by governments into funds nor benefits paid out by funds are included. All figures have been rounded to nearest dollar except for solid waste and sewerage, where rounding would seriously affect results.

[b] Payments from one government to another are excluded to prevent double counting. Thus, if a new $10 million sewerage plant is built by a city with partial assistance of a $3 million grant from the state, the amount recorded is $10 million. The Census Bureau classifies no state government expenditures as solid waste or sewerage; only local expenditures are so classified.

[c] All local government expenditures are included, even if made with state and federal grants-in-aid. See note 2.

[d] This is the census category "sanitation excluding sewerage" and includes street cleaning.

[e] These two counties comprise Massachusetts State Economic Area A, which is slightly different from the Springfield-Chicopee-Holyoke SMSA. Recent data are for the State Economic Area rather than the SMSA, and we have used it for earlier years as well.

[f] Exact population not available for some of years shown; figures calculated using population figures interpolated between known values for other years or, in the case of 1971, extrapolated at recent growth rates.

[g] Inclusion of capital expenditures for these areas would seriously distort growth rates because of lumpiness of new construction.

area, we also show data for: the city of Springfield; all local governments in Hampshire and Hampden counties, an area which the census has been using to report government finances instead of the Springfield-Holyoke-Chicopee metropolitan area; and all local governments in Massachusetts. It is clear that public expenditures for solid waste are relatively small fractions of total expenditures. Even if education and welfare are excluded from the total, solid waste amounts to only about 2 percent of state and local expenditures and 3.5 percent of local alone. Nor do the data show solid waste expenditures growing at spectacular rates relative to other expenditures. They are growing substantially faster than GNP, but so are expenditures for other functions. For the nation, solid waste management seems to be growing at roughly the same rate.

A major problem of interpretation, of course, is raised by the inadequacies of the data. The 1960's were years of continued shift of population not only from rural areas into metropolitan areas, but also out of central cities into densely settled suburban areas with less organized governments and less collection with paid labor. The net effect of these shifts should ideally be separated out from labor cost influences. In addition, there is the question of whether the quality of disposal has been maintained during the suburban shift.

In the Massachusetts and Springfield area comparisons, the comparison depends on what aggregate is used. In no case did solid waste expenditures rise faster than total local government expenditures excluding education and welfare, in the whole state and the two-county area. (In 1967, local governments in Massachusetts had substantial responsibilities for cash assistance to the needy, but by 1971, these had largely been shifted to the state government.)

In the nation as a whole, sewerage expenditures rose at about the same rate as other functions. In the Massachusetts as a whole and in the city and two-county areas, quite the opposite is true; sewerage expenditures grew much faster than all other functions taken together (this is based on operating expenditures alone in sewerage; capital expenditures are omitted because of their extreme lumpiness, which would greatly affect rates of growth).

Labor Requirements of Conventional Handling. The labor intensity becomes even more apparent when unpaid household labor is considered, for it is used with relatively less capital than paid labor. It may be useful to set down the various steps in conventional handling (some of these are also required under wet systems or any other alternative scheme):

1. Collecting waste from various parts of the home, and depositing in storage containers.

2. Carrying loaded containers from house or garage to curb.

3. Lifting loaded containers and emptying into collection vehicle.

4. Carrying empty containers from curb back to house or garage.

5. Driving the collection vehicle safely through city streets, with frequent stops for pickup and compacting.

6. Driving the collection vehicle back and forth between garage, collection areas, and landfill.

7. Operation of equipment at disposal site.

8. Maintenance of collection vehicles and disposal equipment.

Household labor is always used in step 1, and frequently in steps 2 and 4. If there is no paid collection, individuals must also accomplish step 6, in which case the "collection vehicle" is merely the family car. All the other steps are normally done by paid labor if done at all.

If the wet systems method is the alternative, we have only steps 1 and possibly 7 of the above list to contend with. However, we must add some other labor-using steps--the maintenance of grinders in the home, additional maintenance of sewer lines, and additional labor in the operation of sewage treatment plants. The net effect would be a very great reduction in the labor required by virute of the substitution of capital. How much labor is reduced will depend on various factors. For example, if more waste is recycled, the change in labor required will depend on the nature of the material to be reclaimed and on whether, and how, it can be reclaimed in the wet systems approach. For example, the recycling of paper (qua paper) is very labor intensive both under conventional collection methods and wet systems, because in either case it must be separated from other waste at an early step. On the other hand, some glass and metal recycling might be possible under the wet systems approach with very much less labor than with conventional methods.

At present, the relative use of household labor versus paid labor varies greatly from place to place. One can be substituted for the other in conventional methods, without reducing the aggregate amount of labor. However, if household labor is valued less than paid labor, as we argue below it should be, the substitution will genuinely reduce total costs.

There are also opportunities to replace labor with capital in steps 3, 5, and 6, using larger or more sophisticated trucks and fewer workers per ton of refuse collected. There are likely other possibilities for reduction in both capital and labor per ton, through organizational changes and economies of scale by consolidating small operations (public and private). The extent of these opportunities and the degree to which they are exploited are extremely important as to whether conventional methods remain economical and for how long, and we pay more attention to them farther on.

However, in the long run, there are limits on increasing labor productivity imposed by the basic design of American cities and by the need to have disposal sites--landfills or incinerators--somewhat distant from people's residences. The costs of large, clean and quiet collection vehicles are large in themselves, and complicating them to reduce labor in driving and collecting will have some offsets in requiring more maintenance labor (skilled truck mechanics may be a scarce form of labor in the future); beyond some point they will not eliminate enough labor to justify their use. The careful, time consuming attention of at least one person will always be required to operate a vehicle through the streets as they are now laid out; and, ultimately, the narrowness of streets and frequent corners in them will limit the size of the vehicle anyway.

Wages. We turn now to trends in the value of labor, first considering wages of paid labor. In the discussion of the general framework we referred to special factors which might raise wages in an industry faster than in the economy as a whole. There are reasons to expect this in the case of solid waste. The work is physically demanding, dirty, and of no stutus whatsoever. It is also hazardous to a degree far above the average. These highly unfavorable working conditions would appear to be less and less acceptable as time goes on, with men accepting them only as the price of higher wages. Whether they continue, compensated by higher wages, or whether they are improved by incurring costs of other kinds (such as for safer equipment), the effect will be increases over and above the forces affecting other occupations.

There is also the effect of unionization. Unions in solid waste are not new, and sanitation workers' unions in the public sector have traditionally been the most willing to strike, after teachers, even when strikes by government employees faced legal barriers and strong disapproval by the public. In Chapter VIII we go into the question of work stoppages in detail, as a special aspect of labor in conventional methods. Despite the fact that the incidence of work stoppages is already high, there are still some psychological barriers to strikes in the public sector, which will probably fall in the years ahead. This will mean even more work stoppages or the threat of them, in either case with the effect of raising wages. Many private firms are still nonunionized; unionization may well come with the mergers into larger firms, which can be expected in the future. Nor have all municipal forces been organized. A recent study by Stieber[10] of 164,000 "public works" employees in 1,372 cities showed only 51 percent of all workers represented by unions or associations, with 738 of the cities having no employees represented. Of 117 cities over 100,000 in population, 34 had no employees represented.

One observer has noted:[11]

> Usually among the lowest paid public workers in a community, sanitation department employees have been demanding recognition of their unions, wage increases, and improved supplementary benefits. In many parts of the country, most of them are black and are actively supported by civil rights organizations... Between 1966 and 1968, 41 percent of the stoppages, resulting in 48 percent of idleness in the sanitation services, occurred in the South.

In addition to effects of unions on supply of labor at low wages, there are other forces restricting the pool of available low wage labor. The continued breakdown of racial discrimination should open up other jobs for blacks, and make them less willing to accept the low wage, low status jobs in refuse collection. Demographic changes now seem likely to reduce the proportion of young, unskilled workers in the labor force in a decade or two (the recent reduction in birth rates will work itself out to a fall in the proportion of young workers with a 16-25 year or so lag). The gradual increase in education levels will also reduce the proportion of such workers. All of these would have an effect on wages, even without unionization; indeed, unionization itself may partly be only the form in which those other forces express themselves.

Tables 29 and 30 present some available data on wages of workers in the public sector and the private industry, respectively, and recent trends. Table 29 shows census figures on trends in average monthly payrolls of full-time public employees, with comparison to other wages. We have covered the same periods as in Table 28, and also added the two most recent year-to-year changes for which data are available at this writing, from 1969 to 1970 and 1970 to 1971. It is important to note such recent experience because of the acceleration of wage increases in recent years. Also, most of the data for years after 1967 are based only on samples of local governments, so it is useful to have two separate observations of year to year changes. The city of Springfield and the two-county area are not included here because payrolls for them are not available, except for very recent years, and even then, they appear unduly affected by sampling variability or possibly reporting discrepancies (this is suggested by the increases in 1970 and 1971 sometimes being extremely small or even negative). We have not presented the 1970 and 1971 figures for all local governments in Massachusetts for the same reason.

In Table 30, we have data from the Labor Department's annual survey of union wages of "local truckdrivers and helpers" in a number of cities. As part of that survey, the wages of private sanitation employees in a few cities are collected. The data in Table 30 include fringe benefits, whereas the public employee wages in Table 29 do not. The years covered are the same as in the previous table; it should be noted that wage increases in one year are explicitly intended to make up for lower wages in a previous or subsequent year. The 1969-1970 and 1970-1971 data must be interpreted accordingly; the average over the whole two-year period is more meaningful than either one alone.

In absolute terms, wages of solid waste workers are not abysmally low compared to other workers. In the private sector, for example, wages in various cities covered exceed the national average wage, and also wages of other unskilled workers in the same cities. This is partly the result of strong unions in local trucking, which have jurisdiction over solid waste collection as well. In the public sector, wages are generally well below other government employees, but the gap is not extremely large when the comparison is with non-education employees. And they are close to the national average wage, assuming about 168 working hours a month. It

Table 29: Annual rates of change in local government solid waste employee wages and other employees' wages, 1962-1971

Employee Category	Rates of Change in Wages, percent per year					Actual Wage Oct. 1971
	1962-71 average	1962-67 average	1967-71 average	1969-70	1970-71	
Average hourly earnings in U.S. private, non-farm economy (for comparison)[a]	5.0	3.7	6.7	6.7	7.0	$3.49/hr.
Local government solid waste employees:[b]						
Total U.S.	5.9	4.3	7.9	10.2	8.0	$619/mo.
Total for 72 large metropolitan areas			8.8		8.2	$715/mo.
Large cities, special survey[c]					10.4	$786/mo.
Large counties, special survey[c]					11.8	$785/mo.
Total for Massachusetts	6.2	3.1	10.2			$622/mo.
All local government employees:[b]						
Total U.S.	5.7	5.1	6.5	8.2	4.9	$730/mo.
Total for 72 large metropolitan areas	5.7	4.7	6.8		5.0	$815/mo.
Total for Massachusetts	6.3	5.9	6.9			$769/mo.
All local government employees, excluding education:[b]						
Total U.S.	5.9	5.0	7.1	9.3	6.8	$678/mo.
Total for 72 large metropolitan areas	6.1	5.1	7.5		7.1	$774/mo.
Total for Massachusetts	6.6	6.0	7.5			$727/mo.

Note: Blanks in table represent changes not available (except for that for Massachusetts, 1969-70 and 1970-71 changes are available, but seem unduly affected by sampling variation).

Footnotes for Table 29

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[a] *Economic Report of the President*, 1973, p. 228. Wages exclude fringe benefits (for data including fringe benefits, see Table 30). Percentage changes adjusted to eliminate effects of changing overtime and shifts of labor from one industry to another.

[b] Basic data are calculated from U.S. Bureau of Census data on monthly payrolls (excluding fringe benefits) and full-time equivalent employment as of October of each year, as found in various volumes of the *Census of Governments* for 1962 and 1967 (for 1962, Vol. III, *Compendium of Public Employment*; and Vol. VII, No. 21, *Government in Massachusetts*; for 1967, the reports have the same titles and are Vol. III, No. 2, and Vol. VII, No. 21, respectively) and annual reports of the Bureau entitled *Public Employment* (for 1969, 1970, and 1971) and *Local Government Employment in Selected Metropolitan Areas and Large Counties* (for 1970 and 1971). All data for years after 1967 are based on a sample of local governments, except the ones from the "special surveys" identified by footnote 3.

[c] U.S. Bureau of the Census, *Environmental Quality Control, Finances and Employment for Selected Large Governmental Units*, for Fiscal years 1969-70 and 1970-71 (48 largest city and 58 largest county governments).

Table 30: Annual rates of change of wages of private refuse collection and disposal workers, selected cities (including fringe benefits)[a]

Employee and City	Rates of Change in Hourly Wages, percent per year					Actual Hourly Wage July 1971
	1962-71 average	1962-67 average	1967-71 average	1969-70	1970-71	
(All Employees in U.S. economy)[b]	5.8	4.7	7.1	7.2	7.1	$4.54
Boston (drivers and helpers identical)	7.2	4.2	11.0	5.9	17.4	$5.26
Chicago						
Truck driver	3.8	3.4	4.4	5.1	4.4	$4.70
Tractor driver	3.5	3.0	4.1	4.7	4.1	$5.06
Helper	4.0	3.5	4.7	5.4	4.6	$4.51
Load equipment operator	3.4	2.9	3.9	4.6	4.0	$5.23
New York						
Truck with self-contained load unit, driver	5.4	3.5	7.9	18.3	9.0	$4.86
Same helper	5.8	4.0	8.2	19.2	9.3	$4.68
Other truck driver	5.1	3.2	7.4	17.2	8.4	$5.11
Other truck helper	5.5	3.4	8.1	19.5	9.1	$4.81
Tractor hoist operator	5.1	3.4	7.2	17.2	8.5	$5.11
Peoria						
Regular collection driver	6.3	4.1	9.2	9.3	13.8	$4.69
Commercial collection driver	NA	NA	9.1	9.2	13.7	$4.74
Helper	6.5	4.2	9.4	9.5	14.2	$4.59
Pittsburgh						
Driver[c]	4.6	2.5	7.3	5.0	6.4	$3.81[c]
Helper[c]	4.4	2.4	6.8	5.2	6.7	$3.66[c]
Oakland						
Driver	NA	NA	8.0	17.9	6.0	$5.45
Helper	NA	NA	8.0	18.0	5.6	$5.27

Footnotes for Table 30:

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[a]These data are from annual bulletins of the U.S. Bureau of Labor Statistics, entitled Union Wages and Hours: Local Truckdrivers and Helpers, July 1, 19 . Wages include employer contributions to private insurance and pension funds, unless noted otherwise. This wage plus fringes figure has increased somewhat faster than straight wages in almost all cases.

[b]Economic Report of the President, 1973, p. 230. Data are for private, non-farm economy, and are for wages plus employers' contribution for social insurance and private benefits plans. Also includes an estimate of wages, salaries and supplemental payments for the self-employed. The figure in the last column is the annual average for 1971, based on Bureau of Labor Statistics, Handbook of Labor Statistics, 1972.

[c]Pittsburgh data exclude fringe benefits.

may be remembered that many sanitation workers do not work as many hours per week for their pay as other government employees: the incentive system generally leads to very hard work early in the day to allow workers to quit earlier than other workers.

These data thus show what economic theory would call for: much of the unpleasantness and danger and low esteem of the job has already been compensated for by monetary wages. But this does not necessarily vitiate our prediction that undesirable working conditions will force still more increases in the future.

For projection of future resource costs of solid waste management, it is the trends in wages that are important. Table 29 clearly shows that solid waste wages are increasing faster than the average wage in the economy, and faster than the wages of other public employees. This has been expecially noticeable in the late 1960's and early 1970's. The rate of increase in the large governmental units covered by the special surveys of 1970 and 1971 is especially noteworthy, as this figure is based on a complete survey and not a sample.

The picture in Table 30 for private wages is less clear, with extreme differences between cities in the rates of growth. It is clear, however, that in some cities the wages of solid waste workers are rising very much faster than wages of average workers in the economy as a whole. We have also verified that a city-by-city comparison generally shows solid waste wages rising faster than other unskilled workers' wages in the same city. From these data, it would seem reasonable to expect the wages of solid waste employees to rise faster than the average wage, at least one percent per year faster and more likely 2 percent per year faster or more. We can see no offsetting increases in the inherent quality of labor in solid waste handling, for the job requires few skills and they are already in abundant supply.

Value of Household Labor. What of the value of household labor? It is hard to see how one can be other than arbitrary on this. There is no market process to establish values, as there is for paid labor. There are only limited chances for people to express their own valuations by choosing to trade money for their own labor. Usually, finely graduated options are not available, rather "all or nothing" choices are given. People either have house-to-house collection available or not; if there is house-to-house collection, the collecting firm or agency sets a uniform charge (often zero for public collection) and either requires all persons to bring containers to curbside or no persons to do it. People are not given the chance to pay a higher or lower price by doing less or more of the work themselves. Nor is it easy to identify the relevant opportunity foregone; what people would do instead of handling solid waste is not obvious. The task is done infrequently and takes very little time when it is done, and therefore is not really onerous for the average person. We know that many people do all the collection work themselves in order to avoid the price charged for paid collection, even though paid collection is available. This should probably lead us to all kinds of labor, not paid employees in solid waste, is what is relevant, because the job in the household is less onerous than paid work, and unionization is not a factor. (Possibly the increasing participation of housewives in the labor force should be assumed to contribute to an acceleration in the value, because of opportunity costs; we are inclined not to give weight to this because of the infrequency and short duration of the household task.) We can imagine no inherent quality increases in household labor which would mitigate increases in its implicit price.

Capital

Capital is used in conventional collection in the following forms:

1. Containers in the household
2. Collection vehicles (compactor and other trucks)
3. Transfer stations (loading and unloading equipment, compactors, enclosures, large stationary containers)
4. Disposal area equipment and buildings
5. Garages and maintenance equipment

We exclude personal cars, which are used when there is no house-to-house collection. A change in solid waste handling methods would have no effect on households' decisions on car ownership.

The wet systems method would of course use even more capital per unit of refuse collected. Although there would be a reduction in capital needed under headings 2, 4, and 5 above, complete elimination is unlikely. There might be an increase under heading 1 because some nongrindable items are held longer in the home before pickup; there might also be an increase under 3 in some cases. There would be an increase in capital used in sewage collection and treatment. The most important considerations in the present context are the expected future trends in the prices of these capital items, and in interest rates. The true annual cost of a capital item is depreciation on original cost plus interest.

For the whole range of industries in the economy, the price of new buildings has tended to rise much faster than the general price level over a long period. The price of new equipment has sometimes risen faster than the general price level, but more slowly in recent years. Generalizations about interest rates are extremely difficult. For one thing, there are many interest rates, and not complete agreement on which one is the correct one to use in this case. Furthermore, interest rates have shown a strong upward trend since World War II, but there have been sharp fluctuations around the trend. We assume here that true capital costs are expressed as an annualized figure. A given proportional change in original cost will affect the annual cost in the same proportion, but a change in the interest rate will affect it much less. For example, even a doubling of the interest rate from 6 percent to 12 percent would raise annual cost by only 11 percent for an item lasting three years, by 30 percent for an item lasting ten years, by 54 percent for an item lasting twenty years. The longer-lived the asset, the greater proportional effect a given change in the interest rate has. For short-lived items, which are most important in conventional collection, changes in interest rates have limited effects. For the same reason, errors in predicting the interest rate have limited effects on analysis of conventional collection. Longer-lived capital dominates sewage treatment, so the interest rate is much more important. Interest is relevant for land costs, and the land costs of conventional disposal are high, so the interest rate matters a great deal for conventional disposal as well. For a fifty-year life asset, an increase in the interest rate from 6 to 12 percent would raise annual cost 90 percent.

New Plant and Equipment Prices. Table 31 presents some price indices on broad categories of capital goods. Grinders are not included because no previous history exists on them; we already have considered possible unit costs of grinders at various volumes of output in Chapter II.

Prices for the most important capital items in conventional handling have risen less rapidly than other prices lately, if the motor vehicles group is an accurate reflection of prices of trucks used in solid waste. Construction prices, on the other hand, have risen very rapidly, which should be accounted for in projecting the costs of wet systems because it will require large sewerage facilities.

These equipment price trends make inadequate allowance for improvements embodied in the items. As noted earlier, we discuss such improvements here, leaving to a later section improvements in productivity gained by substitution of one input for another, organizational changes, etc. It is certain that the higher priced equipment being bought today is better equipment, in the sense of permitting greater output with the same man-hours of labor as before. This is a general phenomenon in equipment and the published price indices do not attempt to adjust fully for it; they are constructed with an attempt to eliminate from price change the change in production cost due to improvements, but that amount does not reflect the value of the increased output possible from the equipment. That is, the increase in output exceeds the increase in production cost of the capital good. This means that the cost per unit of output has not risen as fast as the price indices in Table 31, if at all. However, we have not yet uncovered comprehensive information on how important this is as a long-term trend. In the absence of that, we can only make some alternative assumptions. A plausible lower bound on rates of increase in capital costs per ton is zero, that is, improvements have just offset the price increases, but not more than offset them. This is suggested by the fact that some of the capital is in the form of buildings, where it is unlikely that there has been much improvement, and the fact that changes in the basic technology of collection vehicles has not been all that radical. The vehicles are now, as they were a decade ago, of the basic "truck" design, have internal combustion engines, and are human-controlled. A plausible upper bound on the increase of equipment costs per ton is one-half the rate of increase in prices of new equipment, which would imply that improvements have offset half the price increases. These seem plausible for predicting the future 10-20 years as

Table 31: Price indices for capital goods and other price indices (1958 = 100)

	1929	1947	1958	1967	1972
Consumer Price Index	59.2	77.3	100	115.5	144.7
GNP Deflator[a]	51.7	76.3	100	114.8	139.5
Nonresidential Structures	35.7	64.4	100	124.0	184.1
Producers' Durable	44.6	64.6	100	109.3	127.5
Wholesale Price Index:					
All Items in Index	51.9	80.9	100	105.7	125.9
Machinery and Equipment alone	NA	60.1	100	111.9	131.9
Motor Vehicles and Equipment alone	42.7	65.3	100	101.9	120.3

[a] Excluding wages of general government employees

Source: Economic Report of the President, 1973, passim.

well. This means that the costs of new capital goods in solid waste collection should increase significantly less rapidly than the general price level, perhaps one or two percent per year less.

Interest Charges. The appropriate interest rate is the opportunity cost of capital. The use of capital in one industry should be charged to that industry at a rate reflecting the value of output which must be sacrificed elsewhere in the economy. Economists have generally suggested an interest rate of about 10-12 percent per year, even though most owners of capital do not pay monetary interest at that rate.

Capital in conventional handling is financed in a variety of ways. Private firms use a combination of debt and equity financing, with the exact arrangements varying with the size of firm . Debt may be in the form of loans from friends or banks, installment credit from equipment dealers, or, in the case of the newer large scale firms, bonds. Equity may be provided by personal savings of proprietors and partners, or by issue of stock to the general public. Merely to suggest relevant magnitudes, assume that a firm uses half debt, half equity financing; that the average interest rate on the debt is 7 percent; that the firm feels it must earn in an average year 8 percent after taxes on its equity in order to make the investment worthwhile; that the income tax rate on its profits is 40 percent and that property taxes are 1.5 percent of original cost of total assets. These seem plausible figures for waste management firms. Although the very recent rise of interest rates makes them too low for this very moment, we may assume that rise is temporary. Then the firm's assets must earn about 11.7 percent in order to cover its interest payments, income taxes, and net 8 percent on equity.[13] This 11.7 percent would represent the cost of capital. Note that the cost of capital is measured by returns without subtracting income and property taxes, because from the point of view of the whole economy taxes represent uses or allocations of output, not reductions in output. These are only illustrative. The rate of return which must be earned on assets varies with many factors: the equity-debt ratio; the interest rate at which the firm can borrow; the property and income tax rates; the profit rate on equity which owners require to keep their capital invested in the business, which will depend on the alternative investment opportunities they have open and the risk in them; etc. For example, assume that the firm could borrow at 5 percent, that the income and property tax rates are as low as 20 percent and 15 percent, respectively, and the firm can rely on debt for 75 percent of its financing. Then the gross rate of return which must be earned on assets would be as low as 6.1 percent. But it is obvious that the interest rates in this example are far too low for most firms in this day and age, and the debt ratio too high.

Municipal Capital. Plants and equipment used by the government should be viewed as having the same opportunity cost as that used by private firms. In solid waste, the capital is essentially identical, and indeed private collection is obviously one of the opportunity uses municipal capital could be put to. In the absence of municipal ownership, the plant and equipment could be used by private firms to collect the very same refuse, so the value of what private capital could produce is a good measure of opportunity cost. Public sewerage facilities have no near counterpart in the private sector, but they are constructed with the same kinds of labor, materials, and machines which could easily have built private capital instead. It is true that local governments bear a smaller share of the total costs that private industry would bear, through a subsidy.

The subsidy which accomplishes this comes about through differential tax treatment:

1. The value of output from municipal capital is not taxed as business income, while private capital's output is.

2. The interest on the municipal debt is exempt from federal personal income taxation, and so municipal bonds can be sold at lower rates of interest.

Local governments also use a combination of debt and "equity" financing. Much equipment is bought out of current property tax revenues. If debt is used, it is less likely to be tied directly to the physical capital than in the private firm. Municipal borrowing is done to provide funds for a variety of functions at the same time; a single bond issue may be used to buy new vehicles and buildings for solid waste, fire and police, and highways and other functions. And it is the general taxing power which is used as security for the loan, not the assets themselves.

While the opportunity cost in the range of 10-12 percent is the appropriate cost to use in evaluation of municipal investments, it is likely that the governments pay attention only to the costs they must bear. They may well disregard the total costs to the aggregate economy and thus take no amount of the real costs of the federal subsidy, which must be borne by taxpayers elsewhere.

On debt, then, they care only for the monetary interest they must pay. Therefore, the future trends in interest rates on municipal bonds will be relevant in shaping attitudes toward various solid waste handling methods. A rise in interest rates would reduce incentives to move toward capital-intensive methods, such as the wet systems one. This, of course, assumes all other things equal, such as the relative part of sewage facility costs borne by higher governments, and the ease of collecting property and local other taxes.

Recent data on interest rates on municipal bonds are shown below, for the annual average of all bonds, and for bonds rated AA by Moody's service, as Springfield's bonds are:[14]

Year	All Bonds	AA Bonds
1965	3.34%	3.25%
1966	4.02	3.88
1967	4.11	3.95
1968	4.45	4.24
1969	5.80	5.70
1970	6.68	6.55
1971	6.12	5.88
1972	5.51	5.38
1973, July	5.44	5.33

These rates contrast sharply with much lower levels in earlier times; during the middle 1950's, for example, high grade municipal bonds could be sold at yields of 2.5 to 3.0 percent per year. Even in boom times of 1929, the average was about 4.25 percent. At this time, interest rates of all kinds are very high. Most observers expect them to fall again considerably, but there is no hope they will fall back to the levels of the distant past. The general upward trend has been attributed partly to accelerated inflation and expectations of inflation remaining at higher levels, and to increased demands for private and public investment in the face of more slowly growing savings and liquidity. The relative importance of these factors is disputed and cannot be determined precisely because neither "expectations" nor "liquidity" is a precise, quantifiable concept. Nor is it possible to make predictions of future changes in interest rates with even as much confidence as is justified in the previous section on wages, and in the next on land costs. We hazard a guess that interest rates in the next 15 years or so will average somewhat less than present levels, so that, say, 10-12 percent is a reasonable estimate of the opportunity cost of capital, and, say, 4.5-5 percent is a reasonable estimate of municipal bond rates which are relevant for budgetary costs of public collection.

put a relatively low value on household labor. It should definitely be less than the going wage rate per hour: much of the work is done by persons who need not do it at the expense of working - children, housewives, retired persons - and even workers can do it quickly and infrequently. On the other hand, the labor is worth something; it is hardly leisure time activity (although in some small towns, the landfill is a social meeting place) and people would surely pay something, even if not much, to avoid it if given the choice.

Furthermore, there are some people for whom the work is onerous, because of their own particular preferences or opportunities lost or physical incapacities. The elderly and infirm are especially likely to find it onerous, doubly so in certain housing configurations. We might assume that the value put on the labor also increases with the income level of the person, all other things equal. We can be sure that in absolute numbers, some people will choose a cheap alternative method if it becomes available.

Much the same problem in measuring the value of household labor is faced in cost-benefit analyses of transportation investments which reduce travel time. One finds little agreement in the literature on that subject, however, except that the value of nonworking time for the average person should be less than the average wage rate. Many different estimates can be found, with per hour values between $1 and $2 held to be most reasonable.[12] If values in that range are accepted for present purposes, household labor is much cheaper labor than paid labor. Any substitution of it for paid labor is substitution of a lower priced resource for a higher priced one, and has the effect of decreasing the real resource cost.

If we use that range of implicit prices, the aggregate value of household labor in conventional collection is by no means negligible. Even if there were house-to-house collection, household labor might be as high as ten minutes per week; at the $2 per hour figure, the total comes to $16.67 per year (10 x 52 weeks = 520 minutes or 8-2/3 hours, times $2 per hour per household). If we go to lower extremes, we might have three minutes per week and $1 per hour, for a total of $2.60 per year (3 x 52 = 156, or 2.6 hours, times $1 per hour). Ten minutes a week at $1 per hour gives $8.33; three minutes at $2 gives $5.20. These amounts are significant in comparison to actual money expenditures for collection and disposal. If there were no house-to-house collection, the time might easily be up to 30 minutes per week or $52 per household per year if $2 is used. Households arrange their activities such that a trip to landfill is often combined with other business, so one must be careful not to overestimate the time and miles attributed to waste handling.

In all cases, we need to remember that not all of the household labor can be eliminated, even under radical changes in handling methods. As with paid labor, we are concerned with trends. Even if the best estimate is less than the hourly wage, we might assume it will increase at the same rate as wage rates. The rate of increase of average wages for

Operating Costs Other than Labor. A complete analysis would take into account the likely increase in fuel and electricity in the coming years, the first being especially important for conventional collection and the second for sewage treatment. Although, these are quite limited in significance, however, compared to labor and capital, the currently anticipated shortages for almost all energy forms may have a substantial impact on the feasibility of technological innovations that are more, rather than less, energy intensive than their predecessors. We shall further address the need for an energy balance study in Chapter IX.

Land

The major use of land in conventional methods is in disposal sites. Small amounts are also used for garages, vehicle parking lots, and transfer stations. The wet systems alternative would reduce the requirments, but impose new requirements for space for sewage treatment plants and sewage sludge disposal. The net effect is expected to be a sizeable reduction. We assume that landfill remains the dominant form of continued disposal well into the future.

The real cost of land for conventional disposal seems bound to rise sharply in the future, if sites reasonably near cities continue to be used, and the prospect of this is in fact a major impetus to a search for alternative handling methods. Some of the costs will show up as monetary costs as new sites are purchased; some will show up as opportunity costs as land already owned by firms and governments is used for disposal instead of other uses; some will show up in the intense political wrangling which accompanies so many searches for new sites - indeed, this may be the most significant real cost in the near future![15]

It seems impossible to predict the future course of land costs in the same way as one might predict wage rates, but it does seem sure they will rise considerably faster than the general price level. This plus the shortage of acceptable sites should make land a factor which contributes significantly to rising costs of conventional systems.

Qualitative evidence on these costs is very visible. We know no quantitative data on trends in prices of land for disposal which would supplement that evidence. Land prices in general are rising much faster than the general price level, especially in the areas near the city which would seem suitable for disposal. However, disposal can use land which is unsuited for most anything else, and the prices and opportunity costs of such land may not be rising rapidly. The political bargaining costs may be just as high for these sites, however, for they depend more on the site being used for landfill than on its not being available for other valuable uses.

The crucial factor in the future will be the extent of regionalization of disposal. Regionalization may reduce the cost in various ways, by exploiting economies of scale in landfill operations and long distance hauling and by enlarging the size of government unit selecting sites, thus making the number of people affected by any given site relatively less influential. The economies of scale should also make it cheaper to run the disposal area with minimum adverse effects on individuals anyway, thus reducing one factor making for objections to a site.

All we have said about the interest rate in the section on capital also applies here, except that the implicit interest rate may be very low for some land which is very unsuited for anything but landfill. Not all land is like the capital discussed above, in being easily transferred to other uses or being built with resources which are easily transferred. Thus, some pieces of land have very low or near zero opportunity cost, and a very low interest rate would be appropriate. This argument is relevant only for land already owned by government when the costs are estimated. For land newly purchased, the market price will reflect the present value of expected returns in private use, discounted at the opportunity cost, and a very low interest rate would be appropriate. Land which is nearly worthless will have a very low market price, which already allows for the low opportunity value. The interest rate applied to such land to record capital costs should be the same rate as on capital.[16]

A major difference is that land, unlike capital, has the possibility of "salvage value" after landfill operations are finished. For the economy as a whole, equipment has very little salvage value; there is a market in used vehicles and they pass from user to user until very little value is left. But with proper landfilling procedures, a piece of land may be worth a great deal even after landfilling is no longer feasible. Indeed, much has been made of alternative land uses at the end of the life of a well-run landfill; recreational uses are most often mentioned. The land may even be worth more than it would have been without landfilling. This factor will help to reduce the real costs of land, and will be an effect heightened by the increase in environmental standards, which will promote better landfill operation in the first place.

However, too much must not be made of this offsetting effect, because the offset comes with much delay and thus has a low discounted present value. The landfill use may continue for 20 years, and then there must be an additional waiting period until the land is used for other purposes. A landfill area will therefore not be available to save other land for a long time. The present value of the future increase in market value may only be 10 to 20 percent of the absolute increase in future value; the discounted present value of a dollar 20 years in the future, at 12 percent, is only 10 cents; for 15 years it is 18 cents. A high discount rate is quite justified here, because the later use is valuable only if it reduces the need to use other land with a high opportunity cost, and because local government officials probably do discount such possibilities heavily anyway.

In the previous pages we have considered possible future developments in prices of resources. These would be sufficient to predict trends in the total cost of conventional handling, assuming it is accomplished as it is now. But in the next two sections we turn to two developments which could seriously alter conclusions reached from resource prices alone. First are some possible changes in environmental standards, or to put it in a way which maintains continuity with the previous discussion, reductions in the extent to which environmental resources are permitted to be degraded. Second, we survey possibilities of increasing productivity by substitutions of one input for another, new organizational changes, economies of scale, etc. The first of the two changes might well raise costs even faster than the prices of labor, capital and land; the second seems certain to offset at least some of the changes in resource prices and environmental standards.

Changing Environmental Standards

Elsewhere we have detailed adverse environmental impacts of conventional handling. There are serious problems which arise from storage in the home, litter from disturbed containers and imperfect handling in collection and transport, noise in collection and disposal (from cans and vehicles), air pollution from vehicles or incinerators, traffic congestion, and a whole host of problems from landfill operation if it is not done carefully. In addition, conventional methods now reclaim a very small amount of household waste for reuse. Society may well become less tolerant of such practices as environmental resources become increasingly scarce and valuable, and their degradation more costly. Clean and quiet streets, clean air, clean water, visual amenity, etc. may become more valuable, and recycling may become more highly regarded. Even if standards are not raised, the valuation of the degradation can increase; that is, society may feel increased loss at the effects of the present standards. If standards are raised, meeting them will require additional monetary costs. Either way, the real costs of conventional methods will be raised.

We feel that there will be reduced tolerance in some respects, but of a selective nature. The externalities in collection do not seem sufficiently harmful to expect much change in attitide, except in some urban ghetto areas where there may be a call for improved collection on public health grounds. Based on our observations in Springfield, noise, traffic congestion, increased litter, etc. do not seem serious enough to play much part. Noise and congestion are probably not going to be serious factors because they usually occur infrequently and are of very short duration in any given neighborhood. Where litter is a serious problem, the marginal contribution from collection is very small relative to the total problem. These are generalizations, and do not mean there will be no cities or parts of cities where the valuation of externalities is increased sharply. But, in the time span we are dealing with here, they seem unlikely to affect real costs by much; perhaps costs will be ten percent or so over levels which would otherwise prevail.

For example, on traffic congestion, we might again refer to estimates of the value of time used in transportation analysis. Our observation in Springfield was that a very liberal estimate of delays to car drivers and bus passengers would be an average delay of 2 minutes for 50 different persons for each days collection on a given route. This is less than two hours of aggregate delay, and using $1.50 per hour would give less than $3 in total cost. Even some addition for extra auto operating costs would make the value of time lost very small compared to the total costs of one day's collection, which would be between $100 and $200. In some areas of the city, the congestion effects are much less than even this example.

The situation may be different in some cities with different street lay outs, of course, so there may be isolated cases of significant delay costs. However, even in those cases, routes can be designed to avoid interference with traffic at very little cost.

The situation seems radically different in disposal. The visual and pollution problems are serious now, and will become less and less tolerable as good sites far removed from population concentrations become more and more scarce. There probably will be little change from the present feeling that any disposal area is a "dump," no matter what it is called, and the present aversion to one being nearby. Water pollution will also have to be reduced sharply in the period under consideration. All these will necessitate much better designed and operated landfills, and in some cases, a resort to more costly incineration as an alternative. A doubling of landfill costs by the late 1980's, due to environmental reasons alone, does not seem out of the question.

As for increased recycling, that would affect conventional costs in several ways. There would be increased costs of labor, perhaps including household labor, and capital. The best guess would be that moral and non-monetary incentives for recycling will not be sufficient to increase recycling greatly very soon. Even if they did, it would be possible that the extra household labor would be performed out of a sense of commitment which makes its real cost negligible. On the other hand, various economic forces may increase the market value of recycled waste, so that the additional benefit more than offsets extra costs. If so, recycling will not in itself have the net effect of increasing the costs of conventional handling.

Increased recycling would reduce land requirements, at the expense of labor, and so is an example of substitution of some inputs for others within the framework of conventional methods. If low value household labor and efficient capital are used in recycling, eliminating some needs for high value land, the net effect will again be to help reduce conventional costs.

On several grounds, then, recycling will probably offset the increase in costs due to raising of environmental standards, if its significance increases much at all. Laudable as it is, however, we would not expect it to become much more significant until monetary rewards for it increase, either in the form of revenue or cost-savings on landfill.

Worker Injuries. The accident rate for refuse collection employees is known to be very high. A recent increase in national concern with occupational safety naturally raises the question whether higher standards will force substantial increases in the costs of conventional collection. The incidence of injuries also raises the question of equity, especially as most refuse workers are relatively poor and uneducated, and many of them are black.

The record on injuries in the industry is clear, and there is also evidence on occupational diseases.[17] The Bureau of Labor Statistics' figures on occupational safety usually show the frequency and severity of injuries and occupational diseases in local government refuse handling are far greater than in manufacturing, and, in frequency, greater than in construction and coal mining.[18] The year 1970, which was the worst for injuries in several years, saw 63.9 injuries and 2,598 days of disability per million man hours worked. The corresponding figures for some other sectors were: manufacturing 15.2 and 759; construction, 28.0 and 2,100; coal mining, 41,6 and 7,792. The year 1969 was more normal, with 48.3 injuries and 1,496 days of disability per million man hours worked, compared to 14.8 and 730 for manufacturing and 28.0 and 2,154 for construction. The general pattern is for more injuries in refuse handling, but for shorter periods of disability than in some other industries. Incidentally, the Bureau's annual reports no longer show injuries in sewerage, but in the years 1960-65, the frequency of injury was about 60 percent as high as in refuse; severity was not reported.

Other data show that public refuse employees have injury frequency rates more than three times as high as the average for all municipal employees and twice as high as other public service occupations deemed hazardous.[19]

The accident records of the city of Springfield show its solid waste forces had the following injury record over the past three years:[20]

Number of injuries	81	123	124
Man Days Lost	922	890	617
Medical and Workmen's Compensation Payments	$19,846	$17,448	$11,237

Wet systems certainly would eliminate many of these injuries and save monetary and nonmonetary costs. However, it seems possible to lower costs even within conventional methods, and recent attention to the problem should help accomplish this. Safety programs for public employees in general have traditionally been neglected. Larger cities tend to have lower accident rates than smaller cities; Stone[21] speculates that one reason for this may be that larger cities have newer equipment, better repair programs, preventive maintenance, and educational programs for employees. This suggests that all cities could reduce injury rates by a modest expenditure compared to the costs of injury.

One must consider the fact that wages in refuse collection have to some extent adjust to compensate partially for the risk of injury and disease. Low as one may think the wages are, they would be still lower if the job were made safer. This is the natural result of employers having to compete for labor with other industries whose work is safer. Employers either pay higher waged directly to workers to offset the risk, or they contribute to health insurance plans which have the same effect. The general consensus in society is that the increased wages do not fully compensate workers for the hazards, however. This may be due to a feeling that workers are not fully aware of the risks, and accept less than fully compensating wages.

The above notwithstanding, it seems likely that public standards will force higher costs to improve working conditions. It is also likely that this will have the effect of moderating the increase in wages, with a partial offsetting effect on total costs.

Improvements in Productivity

There is evidence that substantial increases in productivity are still possible, despite the fundamental limits on continued change in the very long run, which were mentioned in an earlier section. Many of the increases will be discrete, "one-shot" changes, but if they are taken advantage of, they could permit large increases in output per unit of input in some geographical areas, and in the aggregate, they might average 2 or 3 percent per year, which is near the rate for the economy as a whole. Thus, for the next one or two decades, solid waste collection does not yet appear to fall into that group of services where productivity increases are near impossible without radically new technologies. The changes should be possible within the present basic technology - human labor and truck-like vehicle movement of refuse to be disposed of by landfill. However, they seem much more likely in the collection part of the process than in the disposal part.

Before reporting on some empirical studies of these possibilities, we describe them qualitatively, putting them in the framework of this part of the chapter.

Substitution of Household Labor for Paid Labor. This substitution of cheaper man hours for expensive ones can slow down the growth in real labor costs. The effect on monetary costs will be even greater, of course. One main example is in continued elimination of collection from the rear-of-house or garage, and requiring individuals to carry containers to the curb and back. Another would be in the expansion of household labor in presorting of rubbish for recycling, obviating need to expand expensive hired labor.

Substitution of Capital for Labor. Presumably, there will be some slow movement, along past lines, toward large trucks, disposal equipment, etc., even where much capital is already used. The scope for larger pieces of equipment in the transfer and long-haul functions is considerable. Increased capital intensity will be economical in many areas only if larger scale operations are possible, but they would indeed seem forthcoming, as discussed below. The largest jumps in capital intensity should come as the result of instituting house-to-house collection in places where individuals must now transport their own waste to a disposal site. The gradual spread of house-to-house collection depends on a large scale of operations being reached in rural and suburban areas where it is not now feasible.

Substitution of capital for labor does not automatically reduce total costs: the cost of the added capital must not be so great as to outweigh the cost of the labor replaced. If more capital is added, and raises annual capital cost by one dollar, it will lower total cost only if it replaces labor costing one dollar (assuming output remains the same as before). We have no precise information on the nature of the trade-off, i.e., we do not know the shape of the "production function" in conventional handling, but it seems obvious that total costs can be reduced somewhat below what they would otherwise be. The reason for this is that the big improvements do not depend so much on substitution of capital for labor in tiny increments on existing collection routes, or in existing quality landfills, but on large, discrete changes like instituting house-to-house collection, or a regionalization of disposal with major shifts in capital intensity of transport and much larger landfills.

Economies of Scale. These have already been referred to, because they will manifest themselves partly in permitting higher capital intensity. Larger scale operations should also permit more efficient use of both capital and labor by improving routing and scheduling of collection, more flexible maintenance of vehicles, etc. It should also permit the raising of capital at lower rates of interest, for large firms can diversify markets, can engage in complementary markets, and in other ways reduce risk. There has been a great deal of consolidation of private firms by merger to exploit various economies, and there are already some very large enterprises whose shares are traded on stock exchanges. Large firms may also be able to profit from waste reclamation more than smaller ones, by operating large capital facilities and offering a more constant supply of reclaimed waste to users.

Although the growth in waste per person may contribute to some economies of scale in collection, the greater force should be the increasing density of settlement in some rural and suburban areas near large cities. The population of central cities in metropolitan areas is declining, but the loss of scale there should be less serious for costs than the filling-in of areas on the fringe.

Empirical Studies

There is a general awareness that present practice in waste operations in many cities, especially in collection, falls far short of attainable efficiency. The recent spurt of interest in research on the industry, and the pressure of rising labor costs, should push many agencies and private firms to exploit some of the opportunities for improvement.

A number of observers have pointed to the inherent difficulties of achieving efficiency in a public agency operation.[22] Some of the alleged difficulties are: inflexibility of civil service regulations on hiring, firing, disciplining, and rewarding labor; lack of competition; failure to levy user charges which might stimulate economizing behavior by residents and also lead them to express opinions on the value of service relative to costs; low priorities for capital expenditures compared to other municipal functions, which penalize solid waste investment where there are debt limits on municipalities; disregard for elementary business principles of accounting and measurement of opportunity costs, etc. It may be added that regional consolidation of government agencies may be politically impossible, while private firms have been merging into regional or national firms, which offer the opportunity for economies of management, financing and research.[23] A well known study by Ralph Stone and Company[24] concluded that local government systems have generally lagged behind private firms in adopting new technology and in modifying practices to save money. There is undoubtedly a measure of truth to all of these. However, research has discovered possibilities for substantial improvement even within the present institutional framework.

For one thing, there have already been increases in labor productivity in some cities. A study by the Urban Institute and the International City Management Association[25] showed that in a sample of 10 municipalities, the number of tons of refuse collected per man-year of labor increased by an average of 2.7 percent per year between 1968 and 1971. (The tons per man figure for the 10 cities together was computed by weighting the 10 individual figures by expenditures in each city.) The dollar cost per ton rose only very slowly over the three year period, about one per year. This means that the increasing productivity offset a large part of the increases in wage rates and other input prices. The level of service changed in some of the cities during the three-year period, so the figures must be interpreted with care. Some data were available for 7 cities for which costs were purported to be adjusted for service level changes; in them, the tons collected per man-year increased by 6 percent per year over the period. There is no way of knowing how representative the experience of this small number of cities is. It seems impossible that productivity increases of this magnitude could be sustained for more than a few years.

There is evidence that labor productivity in refuse collection varies greatly from one city to another. This variation shows up when certain factors are held constant, such as population and frequency of collection; even in cities similar in those respects, productivity in one may be three times as great as in another, and this even ignores some extreme outliers.[26] This variation seems too great to be explained by differences in capital-labor ratios and difficulty of collection; it suggests instead that efficiency could be improved in many cities where it is now far below the average.

Some further evidence comes from a study of California cities. Wage rates undoubtedly vary from city to city much more than equipment costs, because labor markets are local and equipment markets more regional or national. Thus McFarland, et al.,[27] found that wage rates varied greatly in a group of 30 cities in California in 1967-68. Given that, they hypothesized there would be differences in the labor intensity of collection, with high-wage cities using more equipment in an effort to reduce total costs. However, they found no discernible relationship between wage rates and either capital-labor ratios or capital-output ratios. Nor was there informal evidence that any city was investigating ways to substitute capital for labor in curb-side service, although cities providing backyard carryout service were doing so. The authors suggested that labor costs must rise above some threshold before they stimulate action to substitute capital for labor; the threshold had been reached only for cities offering the service with the highest labor costs, backyard carryout. This suggests that wage increases will eventually push labor costs over the threshold in other cities as well. The authors also suggest that the choice of technology may be constrained by capital budget limits: refuse managers may recognize that additional capital would lower costs, but be unable to get funds to buy it, because of legal debt limits and political obstacles to capital spending.

As mentioned earlier, in some cities a way to lower costs is to eliminate collection of containers from a point in the house, or immediately adjacent to it, and require individual residents to carry containers to the curb. This requirement will undoubtedly impose a hardship on a minority of the population, but overall the substitution of low value household labor for paid labor will reduce total real costs. The monetary costs to the collection agency or firm will fall even more.

A recent study by Clark[28] shows the large savings to a municipality which switches to curb-side collection and introduces other cost-saving measures. A large city[29] halved its collection crews per truck from six to three men. The daily labor cost per route fell about one-half, or about $90; the equipment cost rose only a few dollars per day. The cost per residence served per week thus fell about 40 percent, and the cost per ton about 50 percent, between October and May. Clark ignores the fact that more household labor time was required to replace the paid labor. However, some calculations on plausible values for household labor indicate the cost per residence would still fall dramatically, perhaps by 20-30 percent, if household labor costs were included.

The study by Ralph Stone and Company[30] concluded that even for curbside collection, reductions in the size of crews can increase productivity output per man. In other words, reducing the number of men does not reduce by the same proportion the amount of refuse the crew can collect per hour. The authors used field surveys of both private and public collection, time and motion studies, and mathematical models to investigate the relative costs of one-man crews compared to two or three-man crews, in situations where other relevant factors were held constant. They concluded that a one-man crew can collect more refuse per man hour than larger crews in curb-side or alley collection. Although a one-man crew does need more equipment, this has a negligible effect on total cost per ton, combining labor costs and equipment amortization and operating costs. Furthermore, the work load does not appear excessive for a single man, as far as routine collection from residences and small commercial establishments is concerned. Thus, in a typical case, the total cost per ton can be 25 to 45 percent less than the two-man crews and 35-50 percent less than the three-man crews. However, it was found that multi-man crews are more productive where backyard carryout was performed. This study also pointed out that one-man crews would require a lower level of absenteeism and a higher level of responsibility and loyalty than are typically found in public agency operations.

Conclusions on Trends in Resource Costs

The above discussion has shown a great many factors to be relevant for the future trend in real resource costs. The price of the most important input, labor, will probably increas two or three percent per year faster than wages in general. The price of capital goods may not increase as rapidly as other prices, and inherent improvements in them will further contribute to holding down the increase in costs. A number of changes in organization, scale of operations, and general management efficiency will also contribute to help costs from rising as rapidly as wages. On the other hand, there will be some increasing effect from higher environmental standards, particularly in worker safety and in landfill disposal. These should not be overestimated, but they will play a role.

It is impossible to estimate precisely the total effect. However, we believe that the conclusion should be that the costs of conventional methods will not skyrocket out of sight. They will increase somewhat faster than prices in general. Refer back to our earlier discussion on unit labor costs and prices. Let x be the rate of increase in average wages in the economy, and assume output per man hour increases about 2 percent per year in the typical industry in the economy. Then the unit labor cost of the typical product, and, we assume its price, will increase x-2 percent per year. Now assume that wages in solid waste increase 2 percent faster than other wages, or x + 2 percent per year. Also assume that some large, discrete changes in efficiency and solid waste to rise as rapidly as in other industries, 2 percent per year, for the next decade or so. Then the rate of increase in unit labor costs in solid waste will be (x + 2) - 2, or x percent per year. This is 2 percent faster than for the typical industry in the economy, which is x - 2. A best guess would be that other factors affecting total cost will offset each other, and the total cost rise at the same rate as unit labor cost. That would be two percent faster than the prices in general. This assumption has been used in the total cost comparison between conventional methods and wet systems methods in the generalized cost comparison of the Phase I report, and will again be utilized in the system cost comparisons for Springfield in Chapter IX of this report.

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CHAPTER VII

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2. *Economic Report of the President*, 1973, p. 244. See also Figure 11.

3. *Ibid.*, p. 197.

4. Unit labor cost is wL/Q, where w is the wage rate per hour, and L is the number of labor hours required to produce Q units of output. Alternatively, it is w/(Q/L), where (Q/L) is the productivity of labor (output per man hour). The percentage change of the fraction is the percentage change of w minus the percentage change in Q/L. This rule for percentage change is actually only approximation, but the approximation is very close when the growth rates of w and Q/L are small, say under 10 percent per year.

5. *Economic Report of the President*, 1973, pp. 230, 244.

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9. *Ibid.*, p. 423.

10. *Municipal Yearbook*, 1969, p. 39.

11. White, S. C., "Work Stoppages of Government Employees," *Monthly Labor Review*, December 1969, Vol. 92, No. 12, p. 32.

12. Nelson, J. R., "The Value of Travel Time," in Samuel B. Chase, editor, *Problems in Public Expenditure Analysis.*, Brookings, Washington, 1968; Robert J. Daiute, *Economic Highway Planning*, Chandler-Davis, West Trenton, New Jersey, 1970.

13. This calculation can be explained as follows. Let x be the rate of return required, A total assets, and E equity, so A - E is debt. The firm's profits, after interest and property taxes, are xA -.07(A-E) -.015A. Since the income tax rate is 40 percent, the firm's profits after income tax are .60[xA-.07(A-E)-.015A].

This must equal .08E in our example, so the following equation is solved for x:

$$.08E = .60[xA - .07(A-E) - .015A]$$

Dividing both sides by A, and letting e be E/A, we have:

$$.08e = .60[x - .07(1-e) - .015]$$

In our example, e=.5, so the solution for x is .117. The reader can easily verify that 11.7 cents per dollar of total assets leaves a net profit equal to 4 cents, which is 8 percent return on the equity portion of 50 cents. In general, the cost of capital can be found by solving this equation for x:

$$r_e e = (1-t)\ [x - r_d(1-e) - r_p]$$

where r_e is the rate of return required on equity, r_d is the interest rate on new debt, t is the income tax rate, and r_p the property tax rate.

14. Moody's Bond Record, August 1973.

15. An interesting bit of evidence on problems of finding suitable land is seen in an advertisement "Landfill Wanted" in a recent issue of a solid waste trade journal. The seeker was not identified; responses were to be sent to a box number in care of the journal, and it was noted "All replies will be kept confidential." Solid Wastes Management, October 1972, Vol. 15, No. 10, p. 77.

16. To clarify, assume the annual return on a piece of land is expected to be $100 per year indefinitely into the future, and investors discount the returns at 12 percent, thus establishing a market price of $833. The opportunity cost of land must be determined by applying the 12 percent to $833, giving $100 per year. It would not be appropriate to apply a very low interest rate to a purchase price which is already low due to few opportunities.

17. See the study by Sliepcevich described in C.G. Golueke and P.H. McGauhey, Comprehensive Studies of Solid Waste Management, First and Second Annual Reports, U.S. Public Health Service, Publication 2039, U.S.G.P.O., Washington, 1970, pp. 91-2. See also A.P.W.A. Reporter, February 1973, p. 15; and Ralph Stone, "One-Fourth of Employees' Injuries Due to Back Sprains," Solid Waste Management, July 1972, p. 30. J.M. McFarland, et al., reports that group health insurance rates and workmen's compensation insurance rates are very expensive for collection workers; Comprehensive Studies of Solid Waste Management, Final Report, Sanitary Engineering Research Laboratory, University of California, Berkeley, May 1972, p. 76.

18. See, for example, the latest edition of Bureau of Labor Statistics, Injury Rates by Industry, for 1970, published in 1972 as B.L.S. Report 406. Earlier years are reported in B.L.S. Handbook of Labor Statistics, 1972, Bulletin 1735, U.S.G.P.O., 1972. All data in this paragraph are from these two sources.

19. A.P.W.A. Reporter, op. cit.; Ralph Stone, op. cit.

20. Compiled from data supplied by Department of Public Works, Springfield.

21. Ralph Stone, op. cit.

22. Young, D., How Shall We Collect the Garbage?, Urban Institute, Washington, 1972, pp. 36-38, provides some examples.

23. Ibid., p. 1.

24. U.S. Public Health Service, A Study of Solid Waste Collection Systems Comparing One-Man with Multi-Man Crews, by Ralph Stone and Co., Publication SW-9c, 1969, p. xx.

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27. McFarland, J.M., et al., op. cit., pp. 85-87.

28. Clark, Robert M., "Measurement of Efficiency in Solid Waste Collection," Journal of the Environmental Engineering Division Proceedings of the American Society of Civil Engineers, August 1973, Vol. 99, No. EE4, pp. 447-460.

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CHAPTER VIII

SOCIOECONOMIC ANALYSIS: FINANCIAL AND INSTITUTIONAL IMPACTS

In this chapter we survey briefly how solid waste management is typically financed, and also sewage treatment, which is of interest because of the wet systems alternative. The relevance of user charges, capital versus current expenditures, state and federal grants-in-aid, and issues of equity are discussed. We shall limit the comparison to house-to-house collection and collection of sewage in municipal lines, ignoring both individual handling of solid waste and the use of septic tanks.

Some simple differences between the financing arrangements for solid waste and sewerage are immediately obvious. The role of private finance is considerable in solid waste, negligible in sewerage. Sewage collection is much more capital intensive and so much more financed by debt than solid waste; the capital is much longer lived. State and federal grants to local governments for construction of facilities are very important in sewerage, almost negligible in solid waste. Finally, the extent to which user fees offset the cost of service is much less in solid waste; this could have some minor consequences on the distribution of income, but its major role will be to inhibit adoption of wet systems, as we discuss more fully. There is also a difference in the importance of collective bargaining, which we discuss at the end of the chapter.

Impact on Private Capital

A shift from conventional handling to wet systems would reduce the scope of both private industry and municipal activity in refuse collection and disposal, and increase municipal activity in sewerage. If the shift were widespread, it would replace some frequent private house-to-house collection in sewered areas, leaving only occasional collection of nongrindables. Thus, some investment opportunities will be lost to private enterprise. But as any shift seems bound to be very gradual, and as the total private capital is small relative to the national economy or to any particular metropolitan area, the effect will hardly be noticeable in the aggregate in any one year. Our conclusion here is more optimistic than in the case of labor (see later discussion), because the owners of capital are undoubtedly more capable, on the average, of adjusting to the decline. They can turn their talents and money elsewhere. A very important factor in smoothing the adjustment is the market for used equipment. There is national advertising of used equipment, and it can be transferred to other geographical areas at a cost which is small relative to its value (a ten-year old collection vehicle might still sell for $3,000 to $4,000 in the second hand market). Used equipment is bought and sold by private operators, municipalities, new equipment dealers, and firms specializing in reconditioning and refitting older vehicles.[1] There will still be need for landfills, and the general scarcity should prevent serious decline in value. Naturally, there may be some difficult adjustments and permanently adverse consequences on a few entrepreneurs, but neither the waste of capital, nor the losses to individuals, should be serious enough to count for much in the aggregate picture.

Unemployment

As the primary cost-reducing effect of wet systems is in the elimination of labor in conventional collection, the unemployment problem naturally comes to mind. Indeed, pressure from workers and unions to avoid reductions in municipal forces, and public sympathy for unemployed workers, will be an important barrier to adoption of wet systems. It might be especially strong in a city like Springfield, which is in a labor market area which has had unemployment well above the national average in many years. In April and May 1973, for example, the unemployment rate in the Springfield-Chicopee-Holyoke labor market area was 6.8 percent (in June the flood of students looking for jobs raised it to 8.2 percent, but that was a seasonal increase). The monthly average rates were 8.5 percent in 1971 and 7.9 percent in 1972.[2]

The concern with unemployment is entirely valid in principle. However, we feel it is not a very important consideration in the present context. Any adoption of wet systems should come gradually, and some of the workers laid off in refuse operations will find jobs in the sewerage operation of the same city, or in other public works departments. The small number of workers laid off in any given year would easily be absorbed elsewhere as normal attrition opened up new vacancies. It should be stressed that the case will not be one of massive layoffs, as have occurred or been threatened in cities where refuse collection has been drastically altered overnight, such as by eliminating backyard collection, or by reducing the frequency of collection, and resulted in drastic reduction in crews.

There are about 225,000 workers in the labor force in Springfield's labor market area, and the few workers who would be released outright, not having been transferred to other jobs in the city, would have an almost negligible effect on the total picture. Even a fairly rapid changeover to wet systems by Springfield would take 5 to 10 years, and the number of workers released outright could be as low as 20 per year. Furthermore, refuse work requires no special skill or experience, so the workers will not suddenly find themselves with obsolete human capital which they have built up at cost to themselves. Obviously, the city would find it desirable to smooth the workers' transition to new jobs, perhaps with special unemployment payments and certainly by careful phasing in of new methods. The point is that such extra costs would be very small and should not be a significant barrier to the new method.

Impact on Municipal Finance

On the municipal side, the net financial impact is to decrease expenditures out of current income and to increase expenditures financed by borrowing. The net effect of this depends on the monetary cost comparisons between the two alternative methods - counting only the monetary cost to the local government. This depends on the total monetary cost comparisons in the economy as a whole and on the shares of the costs which local governments must pay, and also on whether waste reclamation brings net profits to municipalities.

A very important factor will be state and federal policy on grants for sewerage facilities construction, which unfortunately is very difficult to predict. The question is whether such grants will be as liberal when facilities handle solid waste. On the one hand, there is a long tradition of sewerage grants, and the federal stance was reaffirmed in the 1972 legislation which mandated higher standards to be achieved. On the other hand, this tradition has been essentially lacking in solid waste. This is not an arbitrary distinction; the principle has been that sewerage aid was needed to prevent pollution of environmental resources, which benefitted numbers of people far greater than the population of a single town or city. This principle is much less applicable to solid waste, although not totally irrelevant there. Especially the federal government would find it hard to justify aid for facilities to handle solid waste, although it has a clear role in research, demonstration, regulation of packaging, incentives for reclamation, etc.

Whatever the federal and state governments decide to do will be crucial for whether wet systems are introduced extensively. For in many areas, the total costs of the two alternatives are bound to be closely matched, and even a small change in the percentage of cost defrayed by grant will tip the scales. This is not to deny that wet systems will sooner or later make some headway in some areas even without any grants to cover the added sewerage costs, or that even extensive grants will not be sufficient in some other areas.

There is another aspect of grants policy which bears mention. All federal sewerage grants are now being made conditional on the municipality levying user charges, which distribute costs to users in proportion to their loads on the system, and sufficient to cover all operation and maintenance (including replacement of components) costs. Some municipalities will have to increase user charges over what they would want to charge in the absence of needing the grant, others will have to institute sewer charges for the first time. This will accentuate the difference between conventional handling and sewage treatment in the relative reliance on user charges, to which we now turn.

The Role of User Charges

Present Reliance on User Charges. In Table 32, we have assembled data on extent of user charges in solid waste and sewerage. We have compared charges to operating expenditure alone, and to operating plus capital expenditures. It is certainly expected that sewer charges will not nearly cover capital expenditures in the year expenditures are made. A more interesting comparison would of course be between charges and the total of operating and capital amortization expense, but this latter figure is not available. To the extent charges exceed operating expenses, they are helping defray at least some capital amortization.

Data for 1970-71[3] show that there is great variation among localities in reliance on user charges. A few cities actually recover more than current operating costs of refuse management: Oklahoma City, Tulsa and San Jose, and also some large counties: Bergen (N.J.), Broward and Dade (Fla.), Fulton (Ga.) On the other hand, some cities levy no service charges at all: Chicago, San Francisco, Oakland, Dallas, Washington, for example, and these large counties: Essex (N.J.), Harris (Tex.), Milwaukee (Wisc.), Orange (Calif.). The data also show there is also considerable variation in reliance on sewer charges. These cities recovered less than ten percent of operating expenses, in sharp contrast to the national picture: Chicago, San Francisco, Los Angeles, Long Beach, Newark, Phoenix; and these counties: Los Angeles, Nassau (N.Y.), Suffolk (N.Y.), Westchester (N.Y.), Jefferson (Ky.), Montgomery (Md.). On the other hand, some recovered more than total operating plus capital expenses: Cincinnati, Denver, Philadelphia, and Broward and Pinellas counties (Fla.).

There are two principal effects of the low reliance on user charges in public solid waste services. The first is that the low price of conventional services will blunt incentives for individual adoption of the wet systems approach if public collection remains available, and also make it hard to get public opinion approval for wholesale adoption in particular municipalities or neighborhoods. The second effect is on the distribution of personal income and welfare in the population of a government jurisdiction.

Effect of User Charges on Adoption of the Wet Systems Method. An important variable for most households will be the value of household labor. As we mentioned earlier, this will vary from person to person due to different opportunity costs, preferences, physical capacity and housing arrangements. We would be sure to find a whole continuum of values, a few valuing the cost of the task at near zero, a few very high, and the rest spread out in between. Some would prefer the alternative wet system even if it cost them a great deal, some would not choose it even if its cost were extremely low. This is as it should be, for household labor counts as a private cost and a social cost. The socially efficient result will be for an individual to choose the wet system if the money cost of the conventional system plus household labor saved minus money cost of alternative is positive. However, this all depends on the money cost reflecting social cost for both systems. In the present case, we observe

Table 32: User charges for solid waste services and sewerage services: charges as a percentage of public expenditures by local governments

Category of Local Governments	Solid Waste 1962	Solid Waste 1967	Solid Waste 1971	Sewerage 1962	Sewerage 1967	Sewerage 1971
Charges as Percentage of Operating Expenditures only:						
All U.S. Local Governments	NA	21	NA	100	101	115
Special Census Survey, 1971[a]						
- 48 Large Cities			10			124
-167 Large Cities			13			117
- 32 Large Counties			58			65
- 96 Large Counties			64			89
-Special Districts[2]			159			64
-Selected Other			27			122
Massachusetts, all local govts.	NA	NA	NA	63	54	NA
Charges as Percentage of Operating Plus Capital Expenditures:						
All U.S. Local Governments	18	19	24	30	35	39
Special Census Survey, 1971[a]						
- 48 Large Cities			9			40
-167 Large Cities			11			40
- 32 Large Counties			51			15
- 96 Large Counties			57			20
-Special Districts[b]			142			30
-Selected Other			24			45
Massachusetts, all local govts.	1	2	NA	18	20	NA

Source: Same Bureau of Census reports on government finances listed in note to Table 28. Blanks indicate information is not available, not necessarily zero user charges.

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[a] The special survey covered the 48 largest cities, and the 32 largest counties with expenditures, without regard to the size of the SMSA's in which they were located. The 167 large cities, 96 large counties, and special districts are the ones in the 38 largest SMSA's; "Selected Other" are all other local governments (smaller cities and towns, townships, etc.) in those 38 largest SMSA's. See sources of Table 27 for citations.

[b] The totals for special sanitation districts are extremely small.

that *both* conventional handling and sewerage are heavily subsidized, the *first* by local governments, the second by federal and state governments as well as local governments (state and federal grants reduce local costs, and not even all the remaining local costs are recovered in charges to users). If we recognize this fact, we see that individual decisions will be made on the same rule as above, but the result will no longer necessarily be socially efficient.

All other things equal, a lower price for conventional systems (relative to its costs) will reduce the number of people for whom the preceding decision rule gives a positive answer, and thus reduce the number of people who stick with the conventional method even though the alternative wet system is socially desirable. Again, all other things equal, a lower price for sewerage (relative to its costs) will *increase* the number of people for whom the decision rule gives a positive value, and increase the number adopting the alternative methods. This is the reason why state and federal grants policy is so important in determining the speed of adoption.

The above discussion has been in terms of individual free choice on adoption of the alternative method. It would have to be somewhat modified if we consider large-scale, compulsory adoptions of the alternative. The modification is that such a large change would open the possibility of individuals sharing in the financial changes in the entire city budget. They are not affected only by the *price* of solid waste services, but also by the amount of taxes which must be levied to cover the costs above and beyond user charge revenue. However, any changes in local tax burden, for example, would still be spread over all the population of taxing jurisdiction. Only if the compulsory charge affected a *very large proportion* of the taxpaying population would people's reactions be greatly affected by changes in the whole budget. If a change affected only one or a few neighborhoods, they would have to share the reduction in taxes with all the rest of the city, and the financial effect on them would be too small to carry weight. Therefore, they would base their reaction on what charges they could save by the change being made. If the charges are very low to start with, the affected population will not encorage the compulsory change unless the grinders are heavily subsidized as well. If the individuals affected have to pay for their own grinders, many more of them will object to the change than would if present user charges for solid waste were higher. Thus, we have low user charges being a strong deterrent to both voluntary individual adoption of the new method and to public acceptance of large scale compulsory adoption in parts of the city. In both cases, low user charges can block a socially desirable change.

User Charges, Efficiency, and Equity

We turn now to an evaluation of the two alternatives on the standard economic criteria of efficiency and equity. The main point under efficiency is how the two alternatives compare in guiding the allocation of resources and in providing incentives to individuals to economize on scarce resources. Under equity, we consider both "horizontal equity" and impacts on income distribution (often called "vertical equity"). Horizontal equity requires that any two persons pay equal amounts for public services if the costs of providing the service to them are equal (costs here mean production costs, plus social costs imposed on other persons minus favorable effects on others, which result from providing the service). What is a "good" distribution of income, or an "improvement" in the distribution cannot be determined without making value judgments; here we adopt the criterion that the net effect of providing and financing services should not increase the degree of inequality. An increase in inequality is a "worsening" of the distribution and we assume it should be avoided. This is a value judgment which seems defensible in the present political context. We do not go as far as to say the net effect should be to decrease inequality significantly, because solid waste hardly seems an important enough function to do much along that line.

We examine efficiency and horizontal equity in this section, and income distribution in the next section. We first point out how present arrangements in the public sector fall short of efficiency and horizontal equity by not relying adequately on the price system, then examine some possible objections to use of the price system. Then we go on to compare conventional and the wet systems approaches. The extensive discussion of the value of the price system is relevant here because, as will be seen, it is easier to use the price system under wet systems; if the price system is useful, wet systems has an advantage.

Value of the Price System. Very little of the cost of solid waste service is defrayed by direct charges to users; most of it is covered by the general government budget. The money is raised by various taxes, but in almost no case are the taxes a family pays very closely correlated with the costs of providing service to it. Whether the tax base be property, or retail purchases, or income, variations in costs from one family to another do not produce corresponding changes in the taxes people pay. The costs of serving two different families might be very different, for example, with Family A generating much more solid waste, recycling much less, and living in an area where collection costs are higher than Family B; yet A and B might pay equal shares, or A even a higher share of the taxes which are levied to cover the costs. Nor will a family's taxes decrease if it makes decisions which reduce costs by changing consumption habits, recycling, or housing location.

Even where charges are made, they are often quite uniform and do not reflect cost differences. This is true of private collection as well. While there are exceptions, both public and private collectors typically use what is called "postage stamp pricing," by analogy with the Post Office's single price for the delivery of a letter to any point in the nation, no matter how far away. If no charges are made at all, we have a special case of postage stamp pricing where the uniform price is zero.

The result is inefficient. Individuals have no incentives to economize on resources which are scarce. Economizing brings no significant gain to them; it merely lowers the cost to the community as a whole and is spread over so many persons that the one whose actions are responsible receives a negligible part of it. The incentive to economize is virtually eliminated.

Postage stamp pricing is found in a number of public and private sectors, and has been named as an important factor in encouraging the low density suburban sprawl which raises the costs of providing the public services.[4] In sewerage, roads, transportation, electricity, gas, and water supply, as well as in solid waste, the greater distances in low density development results in higher service costs per household. Yet the prices charged do not reflect the higher costs; if charged at all, they usually depend only on the quantity of the good or service consumed. If new suburban development raises average costs in a service area, the higher costs are shared by all buyers, even those in the older high density areas, or else are added on to the taxes of all taxpayers. Only a small part of the increase must be paid by residents of the new development. The whole collection of public services for which this is true adds up to a significant factor in subsidizing high cost low density development. Low density obviously has its advantages, and it may be that people would in fact be willing to pay the higher costs if they were forced to. But how do we know this when we have not forced people to make choices in the face of real costs.

Horizontal equity requires that all families have the same difference between the costs of handling their solid waste and the amounts they pay in charges or taxes toward those costs. The costs to remove and dispose of waste is one measure of benefit, so the difference between them and what the family pays may be called net benefit.[5] The above discussion suggests that the absence of user charges violates equity as well as inhibiting efficiency. Where tax payments are not closely related to solid wastes costs, the net benefit will vary widely from one person to another.

Possible Objections. All this said, a number of objections may be raised. First, one might object that solid waste costs by themselves are not large enough to make much difference in efficiency. A better price system for solid waste alone would hardly make a dent in low density development, and the total quantity of resources saved by various kinds of economizing cannot reduce total costs very much. By and large, the objection would go on, the result would be a transfer of costs from taxpayers to users, or some users to other users; while this may be desirable for equity, there is little to be gained in efficiency. This argument could be expressed by saying the elasticity of demand for solid waste services is very low, so that even with an increased price, people will be willing to buy nearly as much as before. In that case, the introduction of prices will not have much effect in reducing the total quantity of resources used. The argument is more plausible when one considers that the service is nearly a necessity and that total expenditures on it are a very small proportion of total family expenditure, two characteristics which make for very low price elasticity of demand. However, there is no thorough empirical study which estimates the elasticity.[6]

In reply, it might be argued that even small efficiency gains are worth pursuing on principle. Forcing people to weigh the costs of their habits in the mundane area of rubbish and garbage may contribute to more general habits of efficiency and to acceptance of the price system in other functions. Furthermore, there may be significant cost savings in some components of handling from even marginal changes in habits. Landfill space is one example. In time, there may also be significant savings in costs of certain raw materials which can be recycled and will be recycled when the price of public collection and disposal is raised to the real costs.

At present, a number of gaps between real costs and market prices encourage excessive use of virgin materials relative to recycled materials.[7] The failure of market prices to reflect the full costs of disposal of waste is only one factor in this imbalance, and raising disposal prices alone would have a limited effect. However, the other factors may well be reduced in the future, and then the gap in disposal will loom larger as a barrier to recycling.

A second objection is that the "transactions costs" of accurate prices are too high, that is, that the administrative and clerical costs of determining costs, billing, and collecting payments would more than offset the savings in other resources. The point of this is reinforced by the "complaint prone" nature of solid waste; mistakes and disputes in cost assessment and record keeping would add ever more complaints. This objection is a potent one. However, there are surely some simple pricing schemes which would fall short of perfection, but still improve the present situation with very little administrative costs. A city might be divided into zones, with prices uniform in each zone, but varying between zones; the result would be better than the result of treating the entire city as a single zone. Other short-cut schemes could be devised which would be better than the zero charge so often used now. A few distinct classes of services might also be established and different charges made for each one. Distinctions can be made on the number of containers accepted, point of pick-up, etc; some localities already vary charges in this way, but many others continue to offer very costly service without levying charges.

A third objection is that the proper handling of domestic waste has favorable benefits to the community as a whole and needs to be subsidized to induce families to see that it is handled properly. Raising the price to full cost would lead individuals to litter, to dispose of waste (secretly if necessary) in places other than landfills, to store waste too long in the home, etc., all of which imposes costs on others. This is all the more likely in the poorest, most densely settled urban areas where solid waste is a serious chronic problem. The only alternative to subsidy, the objection goes on, is to enforce legal rules on proper handling vigorously, but the cost of this would be very high in both money and ill will.

This objection would seem to be the most significant one of all and deserves full consideration. Certainly the externalities referred to must be considered in determining efficiency in a broad sense. A number of observations are in order. First, vigorous enforcement of laws against improper disposal is a genuine option. The objection as stated makes it appear an all or none case. But, enforcement costs may or may not be high in any particular circumstance; in some localities there are very few illicit disposal sites and detection is easy, and the ill will at the enforcement of one more law in an age of a multitude of prohibitions may not be significant. Furthermore, even minimal enforcement can raise the cost of illicit disposal to individuals, enough to induce them to pay the user charge willingly. The objection as stated may justify some subsidy, but not necessarily one of 100 percent. Partial subsidies plus some minimum enforcement of standards would seem to be a preferred middle ground.

A second observation is that even a zero price does not eliminate all problems of illicit disposal; the litter in urban ghettos is a serious problem even when solid waste is collected free, as our observations in Springfield bore out. Litter (the very word is an understatement) in such areas is the product of some basic characteristics of the urban ghettos, and of a much more complicated malaise than user charges for solid waste services. What is needed is more collection effort and basic changes to induce some pride of neighborhood; while complete subsidy may facilitate such changes, it cannot do the job alone.

The situation is very different in neighborhoods of middle and higher incomes and single family homes. Here, illicit disposal is not much of a problem. People can easily afford the user charges and they are not prone to violate the laws on disposal. Again, the combination of some minimal enforcement and some partial subsidy would be much better than 100 percent subsidy.

On efficiency grounds, then, there are no strong objections to raising user charges in the more affluent parts of the city and its suburbs. Indeed, some of the earlier arguments for user charges apply with special force to them. Their affluence is likely to be accompanied by more refuse--more newspapers and magazines go along with higher incomes, lawn waste and leaves go along with single family homes. In addition to sheer quantity, low density housing adds to collection costs. For all of these reasons, it is especially desirable to raise user charges to provide some incentive to save costs. Even if there is little response, at least equity is better served.

On the other hand, there are reasons for subsidizing solid waste handling in poverty areas. If both extremes are found in the same city, it may be difficult to discriminate between the two kinds of neighborhoods by charging more in one area than another. Uniformity of treatment may be more acceptable politically than distinctions to achieve overall efficiency; uniformity may even be required by law. The problem is thus to meet the special needs of the ghetto without abandoning the price system all over the city. The best solution would seem to be to raise user charges to near present costs all over the city, then make additional expenditures on solid waste handling in problem areas, without raising user charges in those areas still further.

Some have suggested that use of the property tax to finance solid waste produces a reasonably equitable distribution of net benefit, because property values are higher in the low density areas where refuse loads are higher and collection costs are higher.

This seems oversimplified. Demographic characteristics are important causes of varying solid waste generation; *a priori*, we would expect elderly people to generate less refuse per household than younger ones. Yet many elderly persons live in property worth as much as younger, large families. Moreover, the property tax is levied on business as well as residential property, yet public collection does not serve business much at all. Business must pay for private collection of its own refuse, which is perfectly reasonable, but it also pays a share of the property taxes which finance collection of household refuse. It thus pays twice, relieving households of part of the cost of servicing them. For the present purpose, it does not matter who ultimately bears this business property tax--that is, it does not matter whether the tax is shifted forward onto consumers or reduces business profits. In either case, the tax payments are not closely correlated with costs of service; for one thing, many consumers of the business's products and receivers of business profits are not even residents of the community in which the business pays property tax.

Comparison of Alternative Methods. It is not inevitable that conventional methods be financed more by taxes than user charges. Nor would wet systems *automatically* result in more reliance on user charges. The technical nature of handling does not dictate financing; we earlier noted the great variation from city to city in the use of charges in both solid waste and sewerage, However, it seems appropriate to compare the two systems taking as given the present differences in financing of government costs, as shown by the national averages.

The picture is clouded, however, by the heavy subsidy from state and local governments in sewerage. Do we measure reliance on charges by their proportion of private costs plus municipal costs, or their proportion of total national costs? The second proportion is much lower. The present subsidy is composed of two parts. The first is the federal tax treatment of municipal interest, which applies to all local capital expenditures financed by borrowing, sewerage among others. The second is the construction grant, which is tied to sewerage *per se*. The first part might be justified on very general grounds--it is essentially a form of revenue sharing. The second part might be justified by considering rivers and lakes as national resources, and assuming localities deserve to be offered heavy subsidies for avoiding polluting those resources. The subsidy does not now seem to be offered as an incentive to avoid pollution, because recent legislation has moved toward prohibiting that in any event.

The first part of the subsidy would continue to operate if sewage treatment plants were enlarged to handle refuse--the extra capital cost would be covered by borrowing at the same interest rates as on other municipal borrowing. We shall assume here that the second part would not be extended to cover such extra capital costs, that is, we assume that localities will have to finance the extra costs of handling solid waste on their own. This is a reasonable assumption given the histories of federal policies on sewerage and solid waste, and the already high grants projected for sanitary sewerage alone. We also assume that grinding costs will not be subsidized, certainly not by state and federal governments. All these assumptions imply that there definitely will be more reliance on user charges in wet systems than there is at present, resulting in an improvement in efficiency.

One important characteristic of wet systems is that the transaction costs of using the price system are much lower in wet systems than under conventional methods, if the load on the sewerage system can continue to be fairly well measured by water flow. Presently, water flow is commonly assumed to be an equitable proxy for sanitary sewerage costs. It is widely used to determine sewerage charges, and is expressly permitted in the new federal regulations on acceptable charge schemes for facilities aided by construction grants.[8] If some households have grinders and others do not, water flow-based charges can be used for all households, but the level of rates would be higher for those with grinders (their charges for conventional collection would be lower, of course).

Water use is already measured for many households and the additional clerical and administrative costs (and compliants) would be very low. If water is not already metered, the advantages of simultaneously measuring water usage, liquid waste loads, and solid waste loads would justify the expense of introducing metering, for the transactions costs would contribute to efficiency and equity for several public services and a much larger block of scarce resources.

Water use is certainly not a perfect measure of waste loads under wet systems. But a charge based on water use would be preferable to no charge at all or a charge completely unrelated to waste flows. The goal in cost assessment cannot be perfection, for the transaction costs are too high for that; it is merely to strike a balance which improves efficiency and equity without using too many resources in measuring and billing. The scope for this seems considerably greater for the wet system approach than for conventional management. (More research is needed to determine the accuracy of water flow as a measure of sewerage costs under wet systems, and some of the recommendations of Chapter IX are directly addressed to this point.)

A byproduct of wet systems and user charges would seem to be improvement in efficiency of use for water in other purposes than grinding, for the amount of money spent on water by a typical household would be more noticeable than at present and make it worthwhile to economize on its use.

Impact on the Distribution of Income

Again, we first analyze the situation under conventional collection, and then compare it to wet systems, assuming in wet systems there is a large increase in the proportion of costs borne directly by households.

Our income distribution criterion is that the financing of solid waste should not increase inequality, which implies that the net benefit not be positively correlated with income. If the choice were between no solid waste collection at all and public collection wholly financed by user charges, there would be no conflict between horizontal equity and our distribution criterion, because in either case, net benefit would be zero for all families. However, we are considering a shift from a situation in which net benefits are not uniform to one in which they would be more uniform. In the process, net benefits will change differently for different people and the distribution of income will change. The reader will remember that in this section, we are considering only effects via consumption and financing; the effects via unemployment, which may well be far greater in magnitude, were considered earlier.

It is important to note first that any impact on the distribution will be extremely minor, and deserves discussion here mostly for sake of analytical completeness and not for practical significance. The amount involved is too small for even full user charges to have much impact on even the lowest income groups. Even if annual solid waste cost per person were as high as $50 per household, the difference between full user charges at one extreme, and completely free service at the other, will not do much to alleviate or worsen poverty.[9]

For a given family, the net benefit from public management of refuse depends on three things:

R = the amount of refuse it generates;

U = the unit cost of handling the community, minus the direct charge to the family;

T = the family's share in the tax payments to defray the part of the costs not covered by charges.

The net benefit is simply total cost of service minus taxes, with cost being RU. Unfortunately, we have little precise information on how each of these varies with income, although we would expect some positive correlation between income and both the quantity of refuse and the unit cost of collection, for reasons already mentioned.

The correlation might be far from perfect, and it might be very weak in many communities. However, along with higher incomes go higher levels of consumption of a wide range of goods, which produce more waste as a byproduct. More particularly, lawn wastes and newspapers and magazines would seem to rise with income. The same is probably also true of packaging wastes because higher income families are more likely to choose the many kinds of convenience packages for food, hardware, etc., which cost money but save time. They are also likely to discard items after a shorter period of use than lower income families, again because their income permits them to buy new items and avoid the time and trouble of frequent breakdown and repair.[10]

It might be noted, however, that some forces operate the other way. Lower income people are more likely to buy inexpensive food in bulk, such as fruits and vegetables, which may actually produce more waste (peelings, for example) than the canned and frozen versions bought by higher income families.[11] Also, higher income families may indeed discard items after little use, but they may discard them by donating them to the poor, directly or indirectly through charity. The poor may discard the items when they are so worn they must go into the rubbish.

However, the direction of correlation is not all that is relevant; it is also important to know how costs vary as a proportion of income. This is especially true because it is common to describe the distribution of the other variable, tax payments, according to how taxes vary as a proportion of income. In the absence of much information, the best guess would be that collection costs vary positively with income, but decline as a percentage of income as income rises. It is hard to believe that the solid waste load is twice as great for a $30,000 income family, for example, as for a $15,000 income one, or six times as great as for a $5,000 income one. Even a generous allowance on the collection cost side, due to the higher costs of low density housing, would not make total collection costs increase faster than proportionately to income.[12]

On the tax side, one can say nothing without specifying the tax which is levied to pay the costs. It is too easy to assume the relevant tax is the property tax, and to approach the problem as one of comparing the variation in property tax with income with the variation of costs. The fact is that property taxes are not the only sources of local revenue. Localities also collect income, sales, and excise taxes, and license fees, and receive large amounts of unearmarked aid from state governments (which in turn levy primarily sales, excise, income and corporate profit taxes). Property taxes account for about 80 percent of local government tax revenue, but in many states local governments are heavily supported by state governments. Property taxes have recently been a third or so of total state and local tax revenues. In 1970 they ranged from 2.4 percent of all state and local revenue (including nontax sources) in Alaska to 41.6 percent in New Hampshire.[13] Which tax pays for refuse collection? That question is hard to answer because it is seldom the case that a change in refuse costs is matched with a change in a particular tax. A package of services increases is usually financed by a package of tax increases, and it is not clear what tax(es) would fall if governments adopted wet systems and raised sewerage user charges.

Here we shall analyze two different possibilities. The first is that all state and local taxes together finance refuse management, and that any change in refuse costs cause a proportional change in all taxes. The second is that the property tax alone is used. For the time being, we assume that federal taxes are not relevant, consistent with our earlier assumption that there would be no significant federal sharing of added sewerage costs due to wet systems. Later we show what difference this assumption makes.

We cannot be very certain in our assessment of the incidence of the taxes to finance public costs. The empirical estimates on tax burden in the economics literature are very tentative. Experts differ markedly in their views, especially on the corporate income tax and, what is more relevant here, the local property tax. One common practice is to present alternative estimates to match different assumptions on tax shifting.

Because of the uncertainty on the ultimate burden of taxes, and because the impact on the distribution of income is in any event very small, we shall present only the general outline of the analysis which would be required to make detailed estimates of the impact. Detailed estimates do not seem worth the cost at this stage.

In Table 33, we present some estimates of incidence, by income class, of state and local taxes. These are estimates by Musgrave, and Musgrave;[14] the "benchmark" estimates are ones based on what they think are the most reasonable assumptions about tax shifting, but they also presented the results of alternative assumptions for some selected income classes. The only variations in assumptions which would make much difference for our analysis are for the property tax, and we show two of their alternatives, both of which make the property tax less regressive than the benchmark estimates.

Analysis for All State and Local Taxes. Consider first the case in which all state and local taxes are changed to offset changes in user charges. From Table 33, we see that the least regressive assumptions on the property tax component produce a distribution which is roughly proportional, that is, total taxes as a share of income really do not vary a great deal over income classes (alternative I). The benchmark estimate is fairly regressive, however. But taxes as a percentage of income do not fall nearly as rapidly as income rises, so that in all cases, the amount of taxes paid does rise markedly with income. The benchmark estimate can be described as in Figure 33, where very schematically the function TT' shows how the taxes paid for solid waste services vary with income. Function TT' is a very rough representation of what is implied in Table 33; the most important thing about it is that it shows the absolute amount of taxes rise with income, but fall slowly as a percentage of income. The general shapes of TT' and CC' (see below) are what are important; the horizontal and vertical scales are merely suggestive.

Table 33: Estimated distribution of tax burdens by income class, 1968 (taxes as percent of total family income)[a]

Income Class[b,c]	Property Taxes			Other State and Local Taxes	Total State and Local Taxes			Federal Taxes
	Bench-mark	Alternatives			Benchmark	Alternatives		
		I[d]	II[e]	Benchmark		I[d]	II[e]	
Under $4,000	6.7			6.7	13.4			15.2
$ 4,000 - $ 5,700	5.7	4.4	5.3	6.8	12.5	11.2	12.1	17.9
$ 5,700 - $ 7,900	4.7			7.2	11.9			20.8
$ 7,900 - $10,400	4.3			7.3	11.6			21.6
$10,400 - $12,500	4.0			7.1	11.1			21.6
$12,500 - $17,500	3.7	3.3	3.3	6.9	10.6	10.2	10.2	23.4
$17,500 - $22,600	3.3			6.4	9.7			22.6
$22,600 - $35,500	3.0			6.1	9.1			23.8
$35,500 - $92,000	2.9	5.4	4.5	4.2	7.1	9.6	8.7	24.5
$92,000 and over	3.3	7.1	5.8	3.6	6.9	10.7	9.4	29.1
All Classes	3.9	3.9	3.9	6.4	10.3	10.3	10.3	22.7

Source: Adapted from Musgrave and Musgrave, _op. cit._, pp. 366-368.

Footnotes to Table 33:

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[a] Basic assumptions on shifting for benchmark estimates. Personal income tax, estate taxes, and social security taxes on employees are not shifted; corporate profits tax one-half shifted onto consumers, one-half on capital income; excises and sales tax and social security taxes on employers - all shifted to consumer; property tax - part on owner-occupied houses not shifted, part on rental housing shifted to tenants, part on business property is half shifted onto consumers and half onto capital income. Data on distribution of various characteristics by income class - actual tax payments, consumption, home ownership, etc. - were used to allocate burden to income class.

[b] Uneven bracket limits were used for computational purposes.

[c] Income here is measured differently from ordinary money income. It includes money income (including transfers) plus value of fringe benefits, imputed rent on owner-occupied housing, interest on life insurance, stockholders' shares of corporate retained profits, and other accrued asset gains (net of losses). The total is about 12 percent higher than money income.

[d] Assumptions on shifting: taxes on owner-occupied housing are not shifted; taxes on rental housing all shifted to tenants; taxes on business property all shifted to consumer.

[e] Assumptions on shifting: some as in note 4 except that taxes on business property are not shifted, but reduce income from capital.

The two alternative estimates for total state and local taxes are not much different in their general pattern except at the very upper end of the scale; there are very few families at those levels anyway, so we confine ourselves to the benchmark case. In Figures 33 and 34 we compare the benchmark estimate of tax burden to two different possibilities for the present distribution of collection costs minus user charges, depicted by the line CC' in each case. In Figure 33, CC' is drawn assuming the costs rise rather slowly with income; in Figure 34, it is drawn assuming the costs rise rather slowly with income to the point of being proprotional above some income level. These two examples should be sufficient to show the essentials of analysis.

In each figure, the vertical distance CC' minus TT' is the net benefit from publicly provided refuse services. If TT' is above CC', net benefit is negative.

If Figure 33 is the more plausible of the two figures, the positive net benefit is concentrated on lower income families and the negative net benefit on higher income families. This would imply that present solid waste financing transfers small amounts of income from upper income families to lower income families, and so is income equalizing to a very minor extent. If Figure 34 is more plausible we have the opposite - present arrangements add to inequality to a very minor extent. As indicated earlier, a slowly rising CC' as in Figure 33 seems more plausible, so the effect of present arrangements would seem to be very mildly equalizing.

A change to wet systems would affect both service costs and taxes under the assumptions we have made. First, assume for the moment that households pay all grinding costs themselves, and as a limiting case that grinders are voluntarily adopted by every household. The grinding costs can then be ignored in our analysis; they are not included in our CC' function. All households can be presumed to have received value in convenience and household labor savings equal to or greater than their annual grinding costs, because they adopted grinders voluntarily. The CC' function would shift down, however, if the wet systems method reduced costs to the municipality, as it was suggested it would in an earlier chapter, and a larger proportion of the costs were financed by user charges. The TT' function would also shift down because less taxes must be collected than before. Assume that TT' always shifts by a distance proportional to its original height at every point, i.e., when taxes are changed every person's tax changes in the same proportion, leaving the distribution by income class unchanged. In the limit, a 100 percent user charge would make both CC' and TT' disappear, there being no costs not covered by user charges and to taxes needing to be collected. Compared to Figure 33, the result would be to wipe out the positive net benefits for low income families and the negative net benefits for high income families and thus have the minor effect of increasing inequality. An intermediate step might be to increase user charges substantially, proportionally to all users, but not to full cost. This

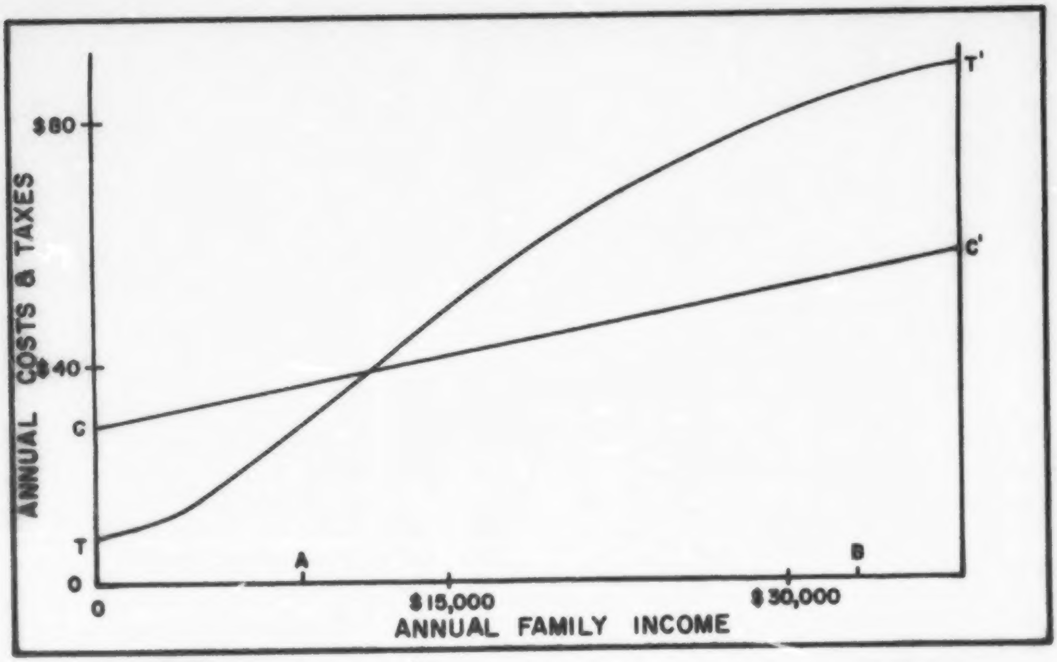

Figure 33: Suggestive comparison of solid waste costs and taxes

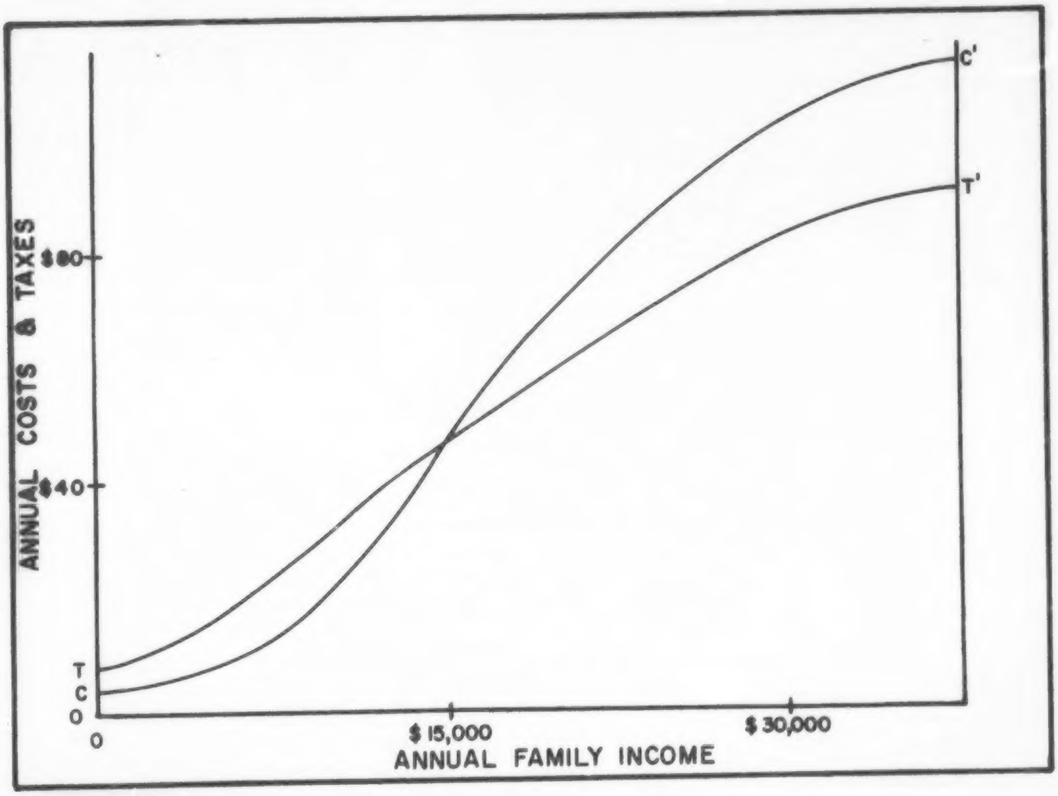

Figure 34: Suggestive comparison of solid waste costs and taxes alternative cost assumption

would shift both CC' and TT' down proportionally from previous levels. For example, a 50 percent reduction is assumed for Figure 35; it also represents some increase in inequality over Figure 33.[16] An increase in user charges by a uniform absolute amount for all households would lower CC' by a constant vertical amount, while lowering TT' by a constant proportional amount as shown in Figure 36. That also would increase inequality compared to Figure 33.[17]

However, all this analysis applies only to the distribution of real income. It does not imply that lower income people are generally worse off in an absolute sense. The net benefit received from voluntary adoption of grinders and the cost savings to the municipality will be distributed to all income classes. What the above analysis does suggest is that the net benefit will be greater for higher income families.

An example may make this clearer. There are two families, Lo and Hi, with pertinent data as follows, before adoption of wet systems; there are no user charges:

	Lo	Hi	Sum
Money Income	$5,000	$20,000	$25,000
Service Costs	30	60	90
Taxes Paid	20	70	90
Net Benefit	10	-10	0
Money Income & Net Benefit	$5,010	$19,990	$25,000

Assume that each buys a grinder and gets a benefit from that proportional to income, e.g., that Lo feels improved to the tune of $50 per year and Hi to the tune of $200. Assume also that service costs are reduced 20 percent for each family, and that full user charges are charged, and taxes fall to zero. Then we have

	Lo	Hi	Sum
Money Income	$5,000	$20,000	$25,000
Gains from Grinder	50	200	250
Net Benefit	0	0	0
Money Income Plus Gains from Grinder Plus Net Benefit	$5,050	$20,200	$25,250

The bottom line in each tabulation expresses total well being (as it is affected by solid waste handling). Both Lo and Hi are better off in the second case, but welfare is slightly less equally distributed, than in the first.

If purchases of grinders are not voluntary, but are compulsory all over a city or some part of the city (e.g., through changes in building codes) we cannot assume that all owners of grinders are at least as well off with them as without. Many may value the benefits very little and will be net losers from any compulsory adoption, quite apart from how they

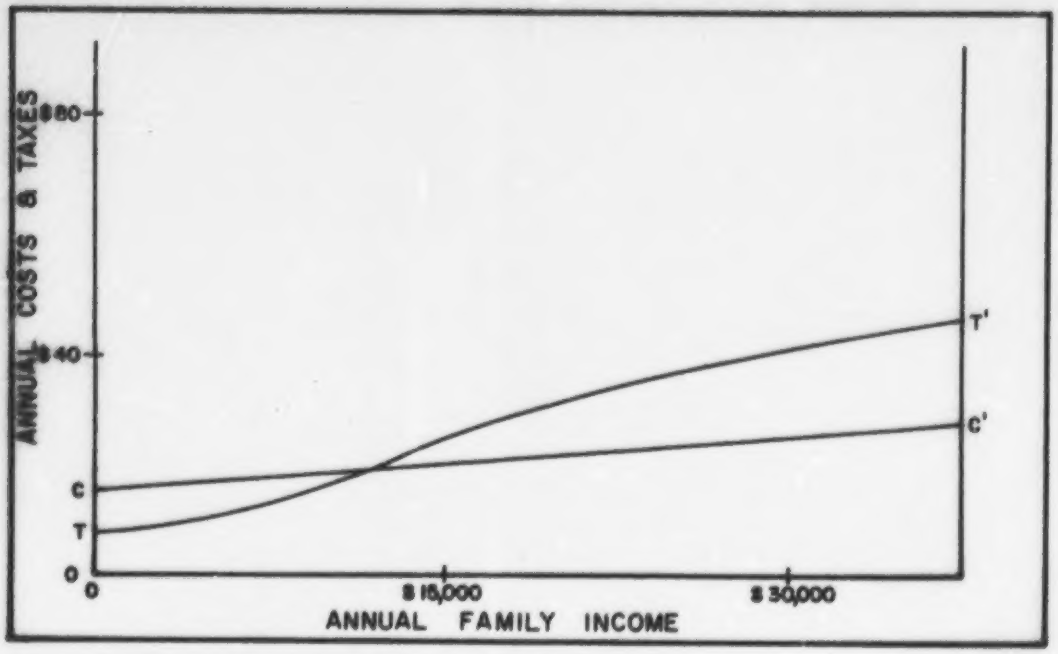

Figure 35: Effect of proportional increase in user charges

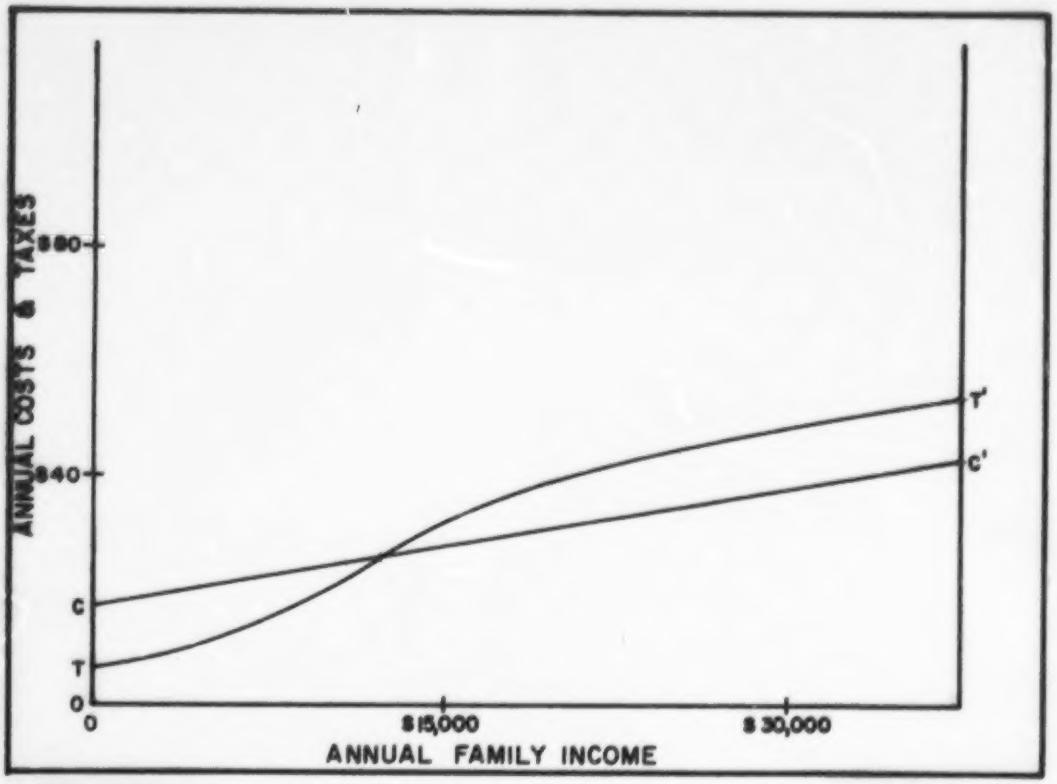

Figure 36: Effect of uniform absolute increase in user charges

fare from the combined increase in user charges and decrease in taxes. The losers may be scattered in all income classes, but the losses would be relatively more burdensome for lower income classes. As grinder costs are higher than collection and disposal costs, the losses could be significant for some. Compulsion would thus augment the tendency to increase inequality.

It may be noted that compulsion is likely only for large areas of newly built housing. Municipalities may see such large scale adoption as offering sizeable savings in conventional collection, and it is more feasible to change building codes for new housing than for existing housing; also, it would be politically more acceptable to refuse to extend frequent refuse collection to new areas than to stop existing service in older areas. All this means that compulsion will be attached to a given home site, not to a given family. Families wanting grinders can buy the new homes, families not wanting them can choose housing elsewhere. The only families winding up with a grinder will be those who are moving from one house to another and who thus have freer choice. This will mean the losses from compulsion will be lessened. However, they will not be completely eliminated, because raising the cost of a part of the total housing stock by requiring grinders will make at least some people worse off than if the grinders were not required. Some people who buy the new houses will be less happy than if the houses were lower priced by not having grinders.

Finally, what if grinders are not universal, but bought by only a part of the population in an area which then continues to be served by conventional collection? In terms of our diagrams, CC' will not shift down all along its length - it is pointless to speak of a generalized CC' function. User charges will rise for some, not for others. But if service costs fall and user charges rise for anyone, the taxes of all will fall - TT' will again fall proportionally. The gains from one family adopting the wet systems method will be spread over all the population. The distributional effect will depend on who adopts the grinders. If, as seems likely, higher income families are the ones who do, the result would be an increase in net benefit for lower income families, but an increased net burden for upper income ones. (Return to the original Lo-Hi example. Assume Hi's service costs minus user charges falls to zero because he buys a grinder and pays 100 percent user charge. This will reduce net numicipal costs by two-thirds to 30, and taxes to 30. But Hi will have to share these savings with Lo; the taxes of both will fall by two-thirds, leaving Lo paying $13.67 and Hi $23.33. Lo's net benefit will be $6.33, Hi's, -$23.33.)

Results with Different CC' Function. If we had started with a different CC' function, the picture would be much less certain. The size of net benefits would likely be smaller, and the pattern across income classes would be very sensitive to small shifts in either CC' or TT'. This is suggested by Figure 34. If user charges were increased proportionally to all users, and the distribution of taxes unchanged when aggregate taxes decreased, the consequent downward shifts of both CC' and TT' would also have extremely small effects which would be very sensitive to exact positions of the curves. Adoption of grinders by upper income groups might have an even more favorable effect on others than before, because the increase in user charges would be greater.

Return to Figure 33. Given the shape of TT', clearly any steepening of CC' will mean that present arrangements are less equalizing, and possibly even contribute to more inequality. However, it also means that an increase in user charges *cum* decrease in taxes will have less objectionable effects than with a flatter CC function: if present arrangements are equalizing, there is less initial effect to wipe out; if present arrangements add to inequality, higher user charges will wipe out the present effect and help reduce inequality.

Analysis for Alternative Taxes. What if we had assumed a more or less regressive distribution for the tax burden? For any *given* shape of CC', a more regressive tax burden (TT' rises more slowly) *means* the present arrangements are less equalizing than otherwise, or conceivably even increase inequality. An increase in user charges would then either have less scope to cancel the equalizing effect, or would actually cancel out some unequalizing effects. Thus the effect of more regressive taxes is to reduce the chance that higher user charges will increase inequality. This makes sense, because user charges *replace* taxes, and the more regressive the taxes, the more inequality is reduced.

Likewise, given the shape of CC', a less regressive tax makes present arrangements more equalizing than otherwise, or reduces any effect they have to increase inequality. The higher user charges would have more scope to reduce equalizing effects and less scope to reduce unequalizing effects. This makes sense because the less regressive are taxes, the less equalizing is the reduction in reliance on taxes, all other things equal.

Property Taxes. The last discussion is directly applicable if we were to assume the property tax were the one to fall when user charges rise. The Musgraves' benchmark estimates (Table 33) show the effective property tax rate falling faster than the rate for all state and local taxes over a wide range of incomes. It does become less regressive and finally a bit progressive at the very top incomes (because part of the tax falls on income from capital, which is large for the highest income classes), but very few people are in those classes.

On our diagram, therefore, the property tax is shown by a flatter function than before. This is shown in Figure 37, where we repeat TT' from Figure 33, and add PP', which roughly represents the benchmark estimates of the property tax from Table 33. Note that PP' must be drawn so as to represent the same amount of revenue as TT'; their relative heights are not shown simply by columns (2) and (6) in Table 33.[18] As before, whether present financing arrangements add to inequality or not depends on the shape of the CC' function. Our previous discussion applies, if the property tax is considered to be the "more regressive" tax of the previous section. If the present arrangements are equalizing, higher

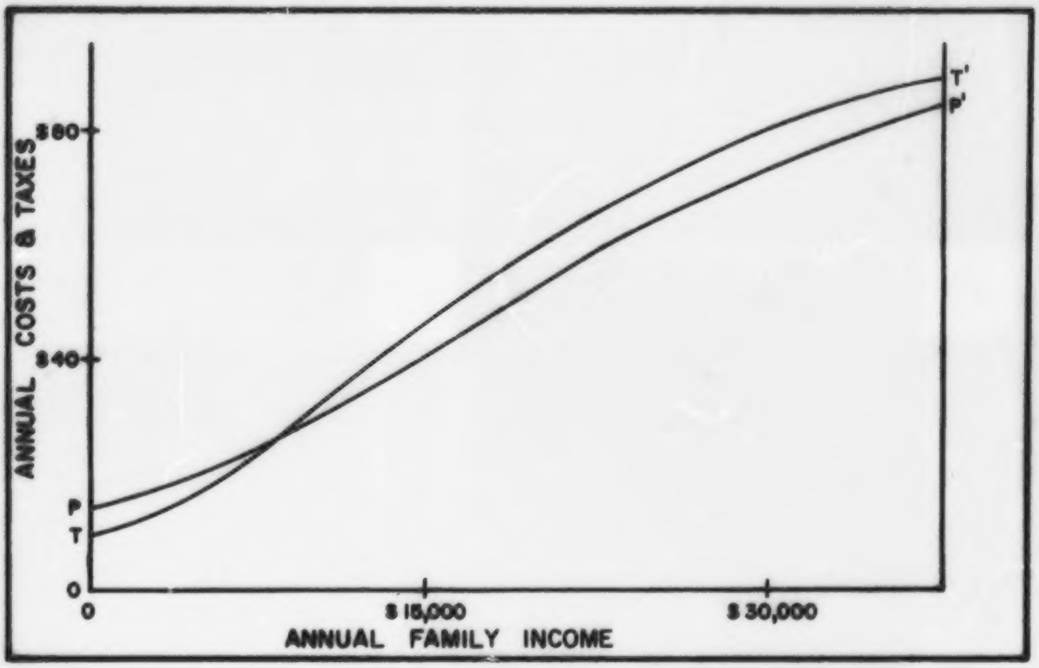

Figure 37: Property taxes compared to all state and local taxes

user charges will offset that effect and the income distribution criterion is not met; if the present effect is to increase inequality, higher user charge will offset that also, and the criterion will be met. Given a particular CC' function, the criterion is more likely to be met under the more regressive property tax than under most other state and local taxes.

On the other hand, alternative estimates of the property tax burden would alter these conclusions greatly. The PP' function implied by alternative 1 in Table 33 would be similar to the one for TT' through the middle income levels, but would then become much steeper. This is because the effective rates rise as incomes rise, so the absolute amount of taxes rises much faster than income. The same is true for alternative II, to a lesser extent. Thus, under either alternative assumption on burden, the previous conclusions on a less regressive tax apply.

Federal Taxes. Federal taxes would be relevant to our analysis if adoption of wet systems would be accompanied by federal construction grants for the expansion of sewerage treatment plants, which so far we have assumed would not happen. Federal taxes are progressive, especially between the lower and middle income classes; see column (9) of Table 33. Thus, a tax function would rise much faster with income than TT'. A shift from present methods to wet systems would then have a definite equalizing effect, assuming the CC' function did not rise very rapidly with income. Compared to Figure 33, the CC' function would shift down, but by less than in Figure 35, because the increase in user charges would be less. The TT' function would become much steeper, shifting down at the lower income end and shifting up at the upper income end.[19]

Conclusions on Income Distribution. First, we reiterate the point that a change toward user charges will have an extremely small effect on the distribution. User charges will replace taxes, and the net effect will depend on the relationship between income and collection costs on one hand, and between income and tax burdens on the other. Neither relationship can be specified precisely. Under the most plausible assumptions, the change would probably cause some extremely small change toward more inequality if all families had grinders and user charges replaced taxes in financing municipal costs. However, if adoption came about voluntarily, lower income families would not necessarily be absolutely worse off. If only upper income families adopted grinders, and paid higher user charges, the effect would be less inequality, because the higher user charges would replace some taxes paid by lower income groups.

Collective Bargaining

Various aspects of collective bargaining offset the choice between conventional systems and alternative systems. Labor relations are relatively very important in conventional collection, because the function is inherently labor intensive and is also important enough for public health and general amenity that disruptions due to labor disputes are very costly. Strikes in some functions have little more effect than to delay production of useful output for a time. The only cost is from the change in time of availability of a product, and that cost may be minor. In refuse collection, however, as in some other public services, even relatively short delays can have serious consequences. Disruptions in sewerage could also be costly, but the system is more mechanized and depends much less on constant, massive labor inputs; this would still be true even if sewerage were expanded to carry and treat solid waste. A work stoppage in sewerage, although possible costly if treatment must be partially cut back, is less likely to cause a public emergency than a refuse collection stoppage.

The nature of the occupation and the vulnerability of the city to work stoppages contribute to union activity and use of strikes or threats of strikes as means of winning higher wages in refuse collection. Refuse collection is no different in this from many other activities in the economy. However, for a long time, legal prohibitions and public opinion inhibited unionization and strikes among public employees. More recently, some of the legal barriers have been falling.

In 1940, Ziskind[20] could already note that strikes by refuse collectors were especially common relative to other government employees: "The removers of refuse, the pariahs of the municipal personnel, have manifested a group consciousness and a maturity of strike techniques that have surpassed by far the protective efforts of the higher paid municipal employees." While he listed refuse collection strikes in 26 cities , Ziskind devoted most attention to their history in New York and Chicago. In 1907 and 1911 in New York, strikes of several days duration were broken by the importation of strike breakers, which occasioned violence. In the 1920's and 1930's, there were seven strikes in Chicago, some several days long, over a variety of issues, such as the attempt of the depression-plagued city to reduce forces or hours and its failure to pay full wages, disputes over rights to jobs in return of political activity (for instance, in 1933, "a spectacular struggle between politicians and trade-union bosses," p. 89), and control of employment at private disposal sites where the city dumped its refuse.

Ziskind also commented on strikes of sewerage workers, contrasting their near-negligible effect on the public with the effect of refuse workers: "The strikes have...never seriously interfered with the normal functioning of existing sewer systems," although they may have retarded the extension or improvement of a system (p. 95).

Over the 1960's, the number of strikes in refuse collection, and man-days idle in strikes, increased greatly, along with other strikes by other government employees. Refuse collection has continued to be one of the government functions most plagued by strikes, although it comes nowhere close to the schools in that respect.[21] Both the costs of strikes and the time, energy and resources expended in collective bargaining must be considered costs of conventional methods of solid waste handling, and costs which will grow as unionization increases employee awareness of wage parity; employees in one function make demands with a view to what others are demanding or have already won at the bargaining table.[22] The unionization of a function for the first time thus has a true marginal effect greater than indicated by the resources devoted to bargaining in that function alone. Another aspect is the predominance of black labor in some municipal collection forces. Some labor disputes have been aggravated by more general civil rights grievances.[23] And it is not only wage negotiations which absorb time and energy; negotiations over working conditions are also costly, in time and possibly in inefficient practices.[24]

All of these factors may make alternative methods appear attractive to many. But one must not forget that alternatives which reduce the scope for labor disputes may have the inevitable consequences of altering the balance of political power in a city, consequences which are impossible to evaluate on economic criteria alone. The true significance of public employee unionism may be as much political as economic. It offers some group (public employees or blacks) the chance to increase their political power. One therefore cannot unequivocally say that an alternative like wet systems would be superior.

Wellington and Winter note that the costs of collective bargaining are less severe when public functions, including refuse collection, are performed by private firms, even if the firms' employees are unionized.[25] There may be times when economic and political forces encourage near-general strikes by all public employees, although such have been rare in fact. Public refuse collection may be stopped even when the collective bargaining issues are less relevant in refuse collection than in some other functions. Also, a private employer may resist union demands more than public employers, because they are better organized and have more experience in bargaining, and because the latter are more open to policical pressure to yield. Governments are organized in ways (division of powers, checks and balances) which make it difficult to present a united front. Even if a city government is forced to intervene in a strike of a private firm, the government is a neutral intervenor and not a direct adversary of the union. The authors also argue that a private employer can offer a more credible threat of unemployment as a result of higher wages - he is better able to substitute capital for labor and is more likely to raise prices to cover higher costs and thus permit a slower growth in demand. And governments seem more able to pass on higher costs to other levels of government, or to hide the increased cost in a complex and little understood budget. For these reasons, a government is more likely to meet a strike with a higher settlement, and thus to be struck in the first place.[26] The authors thus conclude that whether a particular function is appropriate for government now depends in part on the growth of public employee unionism, and they note refuse collection is one example where the choice between public performance and private firms depends partly on unionization. Similarly, the relevance of unionization for conventional handling depends somewhat on whether it is performed by public agencies or not.

All this may be true, but it remains ambiguous how to value these factors. While administrative costs and wages may be kept lower when private firms perform the function, employees are deprived of an avenue of economic power. This consideration may be important in assessing conventional methods versus alternatives. The wet systems method certainly inherently offers municipal workers somewhat less scope for exercising political and economic power. We can say, however, that the total numbers of workers affected by this would be small relative to the total of municipal employees, even if large scale changes were affected. Because any adoption of wet systems is likely to be gradual, the quantitative significance of loss of power will be even less.

REFERENCES

CHAPTER VIII

1. The monthly issues of *Solid Waste Management*, a national trade publication, are a good source of information on the used equipment market.

2. Monthly data are published in U.S. Department of Labor, Manpower Administration, *Area Trends in Employment and Unemployment*, about two months after the month to which the data apply.

3. U.S. Bureau of the Census, *Environmental Quality Control Finances and Employment of Selected Large Governmental Units*, Fiscal Year 1970-1971.

4. See Marion Clawson, *Suburban Land Conversion in the United States*, Baltimore, 1972, for more discussion and reference to empirical studies. See also Milton Kafoglis, "Local Service Charges," in Harry L. Johnson, ed., *State and Local Tax* Problems, Knoxville, Tennesee, 1969.

5. The costs of service are not the only measure of benefit. In theory, another measure is the maximum amount the family could be forced to pay under threat of depriving it of the service. Many families would pay up to the costs of alternative handling, much as their own transport of refuse to the landfill. Economies of scale will normally permit public costs to be well below those costs of alternative handling. However, for some other families, the alternative costs are less than public costs, and the family chooses the public option only because the price is very low or zero. Acceptance and enjoyment of free service does not imply it would be chosen if it were priced nearer its cost.

   The maximum payment cannot be measured, however, so analysis of equity traditionally follows our procedure, which is to use the costs incurred by the public agency as the measure of benefit.

6. McFarland, J.M., *et al.*, analyzed differences in refuse collection per capita among a number of cities in California. They found user charge revenue per unit of refuse, as a price proxy, a significant explanatory variable, when used along with income per capita and population density. For both total refuse, and for refuse collected from households alone, revenue per unit of refuse had a significant negative effect, with implied price elasticities of .70 and .46, respectively. The higher elasticity when non-household refuse is included is to be expected, because the volume of refuse from non-household sources is large enough

to make economizing worth while. However, it is likely that other variables, not included in the analysis, also explain variation in refuse generation, and the estimates could not be taken as indicative of the response of a single city's population to changing user charges. The authors also point out that average revenue as a proxy for price overstates the marginal price actually seen by households - the marginal rates are declining or zero. J.M. McFarland, et al., Comprehensive Studies of Solid Waste Management, Final Report, Sanitary Engineering Research Laboratory, University of California, Berkeley, May 1972, pp. 92-94.

7. Darnay, Arsen and William Franklin, Salvage Markets for Materials in Solid Wastes, U.S. Environmental Protection Agency. U.S. Environmental Protection Agency. U.S. Government Printing Office, Washington, 1972, pp. xx-xxi.

8. Federal Register, Vol. 38, No. 161, August 21, 1973, p. 22527.

9. An increase in user charges would be matched, in the aggregate, by reductions in taxes, so the net effect on most families would be very much smaller than the user charges they pay. To provide some perspective, if the net effect were as much as $20 per year for 30 years, the present value would be $256 at 6 percent, and $157 at 12 percent (12 percent is a plausible discount rate for many families; it is the true interest rate often paid on installment loans). A greater immediate effect might result from a few weeks unemployment, for example, even if unemployment compensation is received.

10. Sheaffer, Tolley, et al., discuss some of the ways in which consumption decisions are interrelated for the household, and develop a modification of the standard microeconomic theory of the household to allow for prices of waste disposal as well as ordinary purchase prices of goods to effect consumer behavior. See John Sheaffer and George Tolley, Decision Making and Solid Waste, Final Report, March 31, 1969 - April 30, 1971, Center for Urban Studies, University of Chicago, 1971, mimeo, ch. IV. The observations in the text are similar to ones made in J.M. McFarland, op. cit., p. 91.

11. Ibid.

12. Sheaffer, Tolley, et al., analyzed differences in solid waste generation in various parts of the city of Chicago. They generally found a positive relationship between income and refuse generated, but the implied income elasticity was much less than one. This would mean that the quantity of refuse rose proportionally slower than income. The Chicago Study is described in more detail later when our own study of collection areas in Springfield is reported on.

This study shows how certain management practices may greatly affect the distribution of benefit of public collection. There is free municipal collection in Chicago, but it is not supplied to residential buildings with more than four dwelling units; residents of such buildings presumably must pay slightly higher rents to offset their landlords' costs of collection and disposal. Those residents will include some from all income classes, because living in large apartment houses is not limited to the poor or the rich; however, detailed analysis showed that the fraction of residents served by free collection in a ward was positively and markedly correlated with median income in the ward. The authors conclude that the effect of the practice is to give subsidies to the rich (pp. IV-18, 48-9),

The study by J.M. McFarland, *et al.*, cited in footnote 6, did find income a significant variable. However, the use of city averages as variables would sharply reduce the range of variation in income and in refuse and perhaps conceal a relationship more visible when individual families are units of observation.

13. Musgrave, Richard and Peggy Musgrave, *Public Theory in Theory and Practice*, New York, 1973, pp. 190-1, 629.

14. *Ibid.*, pp. 366-368.

15. CC' and TT' could easily cross more than once, of course. We shall ignore such cases.

16. Refer to Figure 33, the original position, C, is higher than T for lower incomes; C' is lower than T' for higher incomes. If both CC' and TT' fall by the same proportion, a, the reduction in C is greater than the reduction in T for lower incomes; $C'>T'$ implies $aC'>aT'$, so C' falls by less than T'. This means the positive net benefit, C-T, falls for lower income groups, and the net burden, C'-T' becomes smaller for upper income people.

17. Assume *aggregate* collection costs not covered by charges falls by t percent. If the costs of all persons fall by some constant absolute amount, the proportional reduction for lower income persons, t_L, is greater than t. The corresponding reduction for upper income people, t_u, is less than t. For lower income people, costs fall by $\Delta C-t_L$ times C; their taxes fall by $\Delta T-t$ times T. Since $t_L>t$ and $C>T$, clearly $\Delta C>\Delta T$, and the positive net benefit, C-T, falls.

    For upper income people, $t_u<t$, and $C'<T'$. The cost reduction is $\Delta C'-t_u C'$ and tax reduction is $\Delta T'=tT'$. Since $t_u<t$ and $C'<T'$, clearly $\Delta C'<\Delta T'$, and the net burden, C'-T', becomes smaller.

18. In Table 33, the average property tax rate, for all incomes combined, is 3.9 percent, compared to 10.3 percent for all taxes. If property taxes were raised high enough to fill all revenue requirements, without changing the distribution, all the effective rates in Table 33 would have to be multiplied by 2.6 (= 10.3/3.9). Now assume k percent of total tax revenue goes to pay refuse service costs. Then the TT' function must be based on k percent of column 6 in Table 33, while PP' must be based on 2.6k percent of column 2. Note that Figure 33 is another case in which the areas on each side of the intersection of the two curves are not equal, because the number of families is not the same for all points on the horizontal axis.

19. This can be verified by applying the same principle as in footnote 17.

20. Ziskind, David, One Thousand Strikes of Government Employees, Columbia U.P., 1940, pp. 94-5.

21. For extensive data on strikes in public employment, see Harry H. Wellington and Ralph K. Winter, Jr., The Unions and the Cities, Brookings, Washington, 1971, Appendix B; U.S. Bureau of Labor Statistics, Work Stoppages in Government, 1958-68, Report 348, 1970; see also the Bureau of Labor Statistics annual bulletin, Analysis of Work Stoppages, the latest of which is for work stoppages in 1971 (Bulletin 1777, published in 1973). Work stoppages by sewerage workers are not reported separately by the BLS, but are combined with other occupations in a wider category.

22. Wellington and Winter, op. cit., p. 61; David T, Stanley, Managing Local Government Under Union Pressure, Brookings, Washington, 1972, p. 68, 79. Stanley notes a case where an unusual increase for sanitation men resulted in a larger-than-planned increase for police and firemen as well.

23. Stanley, op. cit., pp. 3, 68; also W. Donald Heisel, "Anatomy of a Strike," Public Personnel Review, Vol. XXX, No. 4, October 1969, pp. 226-32, where details are given of a strike of public employees (refuse collectors and others) in which racial feelings were a factor.

24. Stanley, op. cit., cites many examples, including some in refuse collection.

25. Wellington and Winter, op. cit., pp. 62-4.

26. Ibid., pp. 195-6.

CHAPTER IX

SUMMARY AND CONCLUSIONS

Economic Feasibility

The estimated total system costs, on an annual per household basis, for both the wet system and a continuation of existing conventional practice are shown on Table 34. The 1988 costs, which are shown in terms of 1973 dollars, have been derived on the basis discussed in Chapter VIII, utilizing a two percent annual increase in labor costs. A comparison of the system totals is even more unfavorable to the wet system than the generalized comparisons of Phase I (where the 1973 figures were estimated at $125-$182 for the wet system as against $43-$101 for conventional practice). Evidently, conventional waste management practices in Springfield are very efficient, with per household costs at the very bottom of the national spectrum.

But it should be reiterated that the $80-$105 annual cost of grinding is that for the Foster-Miller or Nebiker-Meier grinding concepts, both of which were rejected in Chapter II on the basis of excessive cost. Moreover, this is an annualized cost, which, again as noted previously, is not the basis upon which individuals would base a decision on grinder purchase. Consequently, the totals inclusive of grinding do not appear very useful.

If the cost of grinding is excluded, on the assumption that grinding costs would be borne by the householder, then the remaining costs are those to just the public sector, and these are considerably more favorable to the wet system, possibly 10 to 15 percent lower than conventional by 1988. Because this margin is rather small, the conclusion would be that implementation of the wet systems concept is still very distant. Yet on the other hand, if our prediction of potential consumer acceptance is correct, implying heavy involvement of the private sector appliance industry in developing and marketing refuse grinders, then it behoves the public sector to examine the consequences on its waste management systems, as it might otherwise be faced with the necessity of banning refuse grinders.

Other than the grinding cost component, most of the uncertainty in the wet system cost is attributable to the cost of sewer maintenance. As explained in Chapter IV, it is simply not yet possible to determine the necessary flushing frequency; yet it is the flushing frequency that primarily determines sewer maintenance costs. If flushing is necessary four times rather than only once per year, then the $6-$9 range assumed in Table 34 for 1973 would rise to $24-$36.

A problem perhaps inadequately addressed in the economic analysis is that of transition costs, i.e., the costs during that period when both conventional systems and wet systems coexist. The cost items for sewage treatment, sewer maintenance and grinding might be assumed to rise

Table 34: Total annual system cost per household comparisons for Springfield

	1973		1988	
	Conventional	Wet System	Conventional	Wet System
Refuse Collection	$17.50	-	$21.50	-
Collection of Nongrindables	-	$2.50	-	$4.00
Bulky Refuse Collection	1.00	2.00	1.50	3.00
Disposal	3.50	1.00	4.50	1.50
Sewer Maintenance	2.00	6.00-9.00	3.75	7.50-11.00
Grinding	-	80-105	-	80-105
Treatment	9.00	12.50	10.00	14.00
Sludge Handling	5.50	8.50	6.00	10.00
Sludge Disposal	0.75	2.00	1.00	2.50
Total	$39.25	$114.50-142.50	$48.25	$122.50-151.00
Total to Public Sector (Excluding Grinder)	$39.25	$ 34.50-37.50	$48.25	$ 42.50-46.00

linearly with increasing number of installed grinders; however, it is unclear whether the cost items for collection and disposal would also decrease linearly, and thus the possibility of a higher than expected transitional cost cannot be discounted. It may therefore be only at the point of complete implementation of the wet system that the expected wet system costs are attained. But until such time as the necessary detailed data on refuse characteristics becomes available, data that was unavailable to us, any attempt at quantifying the transition would be excessively speculative. This is not, however, to deny the importance of the problem.

Technical Feasibility

Collection of Nongrindables. The lengthy but in retrospect very important analysis of the existing solid waste management practices in Springfield has uncovered numerous potential problems of wet system implementation that have hitherto received little or no attention. Certain of the particular institutional problems that might affect implementation of the wet systems concept in Springfield, such as the mandatory regionalization and assessment scheme currently under consideration by the state, are obviously unique to Massachusetts and need not apply to other metropolitan areas. But many of the other phenomena uncovered in our analysis would appear to be applicable, albeit perhaps to a lesser or even greater degree, in almost all areas of the country.

The presence of seasonal peaks in refuse generation, especially in spring and fall, implies problems for both grinding and for treatment. The fall peak, as shown by the calculations of Chapter IV, would require large amounts of freshwater to supplement recycled wastewater if limiting refuse concentrations in the sewer system are to be met. And on the assumption that adequate grinding water is available, then the load variation solids concentration, rising from 1200 ppm in winter to 1850 ppm in fall. If indeed adequate grinding water is not available to cover the fall peak, then clearly additional conventional collection would be necessary during this time of year.

Bulky refuse is likely to be more problematic under a future wet system implementation than under today's practices. Even though bulky refuse is collected in Springfield by a special collection on an appointment basis, our observations and analyses show that many of the smaller bulky items are routinely picked up by the collection crews during normal collection. Indeed, we have established that the spring peak is at least in part due to a relatively high fraction of attic wastes. It is also clear that many of these items, even though grindable in theory, would not be so in practice. Wood and plastic toys, old radios and kitchen appliances, or small pieces of furniture are all items that can readily be included into a normal refuse container, and therefore do not appear in the figures for bulky items. Yet feasibility of grinding such items is questionable, and hence one may conclude that the frequency of the by appointment bulky item collection would unquestionably increase.

Unfortunately, we cannot make a definitive quantitative judgment on such an increase because the necessary data is not available.

Exclusion of Refuse Categories. As noted in the Phase I report, metals must be excluded from sewer transport not only for reasons of problems in hydraulic transport, but also for reasons of limitations in the grinding process. A refuse grinder capable of grinding metals would require power levels beyond normal residential service and would be even more costly than already envisaged. The question of whether or not glass and ceramic material must also be excluded is less easy to answer. Certainly the flows actually encountered in many parts of the Springfield sewer system are insufficient to attain necessary 2.5 ft/sec (0.76 m/sec) scour velocities as determined by Foster-Miller, and a deposition of glass must therefore be assumed. The alternative of steeper slopes for gravity sewers must be rejected on economic grounds. Consequently, if glass is introduced into the sewer, an intensified preventative maintenance program will be necessary. Calculations show that the annual per household cost of such a program is about 4y dollars, where y is the yearly frequency of flushing. If flushing were required 2 or 3 times per year, the cost would be reasonable and well within the $5 to $28 range anticipated by the Phase I study for a city of Springfield's size class. On the other hand, if the frequency is much above this, the economics of the wet system become progressively more unfavorable. Yet in the absence of actual experience, or even laboratory studies on gradual accumulation of glass and its effect on flow and possibly synergistic consequences on the rate of deposition or sewer blockages, this necessary frequency is almost impossible to predict. Discussions with manufacturers of modern pressure jet flushing systems and with those in Springfield experienced in sewer maintenance yielded a diversity of opinions. This question, therefore, remains one of the major uncertainties of a wet system implementation.

One might perhaps note that the alternative of separation of glass from the refuse stream prior to grinding, and storage until the time of nongrindable collection, is not regarded as feasible. Presently a majority of the glass fraction is beverage containers, whose storage over several weeks if not months would require probably excessive storage space. Moreover, because of this long storage period, such glassware would need to be washed to remove putrescible remnants. By the same token, however, it should be noted that glass beverage containers constitute at least 50 percent of the glass and ceramics fraction in residential refuse, and thus successful incentives for beverage container recycling would have a very positive effect on both the cost and feasibility of a wet systems implementation.

Grinders in Multifamily Housing. We have identified substantial economies of scale in grinding, and thus strong incentives for installation of a single grinder in multifamily housing. Unfortunately such economies in initial cost will probably be offset by much higher maintenance and repair costs. We see problems in this respect not so much in garden apartments, condominiums or high income high-rise structures, but in low income multifamily housing and in the 3 or 4 story multifamily housing that characterizes residential areas immediately beyond the central business districts. The problems of vandalism, ownership and maintenance responsibility in such areas are not to be dismissed lightly, and it is very difficult to envisage even public or utility ownership and maintenance of grinders at reasonable cost and effort.

The Problem of Commercial Refuse. Although our major focus has been on residential refuse, it has been very difficult to exclude consideration of commercial refuse, especially in Springfield where many commercial establishments are served by the regular collection. To the extent that commercial refuse is largely paper and discarded packaging, and especially that of neighborhood stores or offices, it is quite probable that such establishments could also utilize the wet systems method. This would presuppose, however, a very rigidly enforced ordinance as to the categories of refuse allowed. Shopping centers or the concentration of commercial establishments and offices in the downtown central business district would probably need to rely exclusively on private collection service, if for no other reason that the high refuse to sewage ratios to be expected and the consequent problems of inadequate grinding water.

A superficial interpretation of the preceding paragraphs, which might read more like an inventory of problems than a judgment of feasibility, would allow the conclusion that the wet systems concept is so beset with difficulties that it is hardly worth further serious consideration. However, the reader is reminded that the purpose of this study has been to ensure that all possible questions have in fact been addressed. Moreover, the factual evidence available to us is contained in the few laboratory studies conducted by Foster-Miller, and all the rest is circumstantial, based solely on our judgments and experience. And consequently, objectivity could only be preserved by taking an inherently conservative approach.

Scour Velocities in Hydraulic Transport. Perhaps the most surprising revelation of our case study was the fact that so many collector sewers are not only laid at less than minimum slope, but also rarely flow even half full. Yet to those familiar with the design and construction of sewer systems, this is hardly a revelation, as the incentives for as low a slope as possible are well understood. Nevertheless, the previously assumed feasibility of hydraulic transport, based on the premise that the necessary scour velocity (of 2.5 ft/sec) would be generally encountered because 2.5 ft/sec is the recommended design minimum, is clearly shown to be highly questionable. Thus the possibility that glass must be excluded from the sewer is very real. Yet this in turn has implications for the grinder design, which, if glass were to be excluded, might be a very much simpler device, possibly just an oversized garbage grinder. Evidently, then, much rests upon some unequivocal answers to question of the feasibility of hydraulic transport, answers which require further laboratory study and which we could not address within the confines of a desk-top analysis.

Freshwater Demands. Again the inadequacies of the available data have prevented any firm conclusions on the quantity of freshwater that would in fact be necessary. Under the most unfavorable circumstances per capita water consumption might be increased by 40 percent during the peak of refuse generation during the fall months. And even under favorable circumstances, the increase might be 6 to 10 percent over the entire year. Clear answers can be given only if data is available on daily refuse and sewage generation for individual households, data that is not available for any urban area in the United States, let alone for the Springfield study area.

Non-Newtonian Flow Regimes. The analysis of hydraulic transport raised the possibility of transporting ground refuse in sewers at concentrations in excess of critical, that is, under non-Newtonian flow regimes. Several advantages might be postulated for such an alternative: little or no freshwater would be needed to supplement the limited quantity of recycled water (e.g., laundry effluents) that is readily available; at high solids concentrations the matrix effect results in even the heavier particles being kept in suspension, thus obviating the need for scour velocity to remove accumulated materials. Indeed, it might be argued that since the majority of lateral sewers flow at less than half-full even during peaks, the increased head losses of such flow regimes would not be serious because the sewers would merely be flowing fuller but rarely reach or even exceed full flow at which point hydraulic capacity would be compromised.

Treatment. Perhaps the only major conclusion regarding treatment that has not already been discussed at some length in Chapter IV of the Phase I report concerns the incompatibility of wet systems with what appear to be the most recent trends in treatment facility design. Several aspects of the planned secondary facility for Springfield are of concern; the separation of grit following primary sedimentation; separate treatment chains for primary and secondary sludges; and the sophisticated physical-chemical sludge treatment process of wet oxidation. If these are at all typical of recent nationwide design trends, then the degree of modification required for adequate treatment of ground refuse will be substantially greater than might be expected on the basis of the older traditional process configurations.

A Definitive Judgment

Having seen most of the generalizations of the Preliminary Assessment to hold true for the case study area, having seen the cost comparisons to be very unfavorable, both in terms of a general analysis as in the particular case of Springfield, and having uncovered some additional technical problems during the case study that had hitherto received inadequate attention, what, then, is our final judgment on the concept?

Unfortunately, the complexity of the concept and its place within the many interlinked efforts at rational environmental management make any definitive pronouncement on the concept at the present time a very dangerous undertaking. The major reason for our reluctance to express absolute conclusions is the limited information on the technical aspects of the concept that is to date available. Taken at face value, the results of the economic analysis presented in these pages is indeed unfavorable to the wet systems concept, showing approximately a doubling of total per household cost for all the elements of domestic waste management. Yet at the same time we have shown that if the cost of the grinder is borne by the householder, there may be situations where the cost of the wet systems concept to the public sector may be less than any conceivable improvement of today's concepts. Thus given the premise of technical feasibility, we arrive at the conclusion that its economic feasibility, by which we mean that cost is no greater than that of its competitive alternatives, rests upon the willingness of householders to purchase a grinder for benefits of convenience and aesthetic or environmental improvement of their homes. Such a premise is not to be dismissed lightly, given the indications of continuing increases in disposable income. And sceptics might be reminded of the realities of the current market for trash compactors, an appliance that surely offers fewer convenience benefits than refuse grinders.

Certainly we may conclude that domonstration scale research investments are as yet unwarranted. At the same time, however, we believe that a limited program of further studies directed specifically at the resolution of a few key technological uncertainties would allow judgments that are based on more substantial evidence than the largely circumstantial inferences that are available to us at the present time. If these further studies, as elaborated in the following section, have favorable results, then we believe that the wet systems concept would gain consumer acceptance to the point where implementation became feasible. This is contingent, however, not only on a confirmation of technical feasibility, but on the availability of a grinder whose cost is compatible with consumer acceptance.

Recommended Program of Further Investigations

The preliminary technical and economic assessment and the detailed case study of wet systems undertaken in the course of our investigation have pinpointed several areas of technical uncertainty, and consequently no definitive judgment on the technical feasibility of the idea could be made at this time. However, it has been possible to analyse these uncertainties to the point where a program of a few selected, but pertinent, investigations could resolve these unanswered questions, and to this end we have set forth a program of research tasks. The sequence of tasks is ordered in such a way that the most critical questions be addressed first, and so that further investments may be terminated if the results of the most critical investigations are negative.

Because these significant technical questions have yet to be resolved, we feel that investment of research monies at the level required for demonstration scale project would be premature, and a decision on such investments should be preceded by the program of laboratory scale studies herein described. A detailed analysis of the quality parameters and conventional treatability of ground refuse-sewage mixtures may be regarded as a first priority, and is already under consideration as an in-house study at the EPA National Environmental Research Center in Cincinnati. The information yielded by this study will considerably extend the existing knowledge on the subject developed by the Metcalf and Eddy investigations, and will allow much more reliable estimates to be made for the likely cost of treatment. There remain to be addressed, however, the following series of tasks, presented in the recommended sequence. Note that Task 5 is probably the most costly, and should therefore be undertaken after the other, relatively cheaper, tasks.

Task 1: Hydraulic Studies Under Unsteady Flow Conditions. The most important *known* limitation to the technical feasibility of the wet systems concept concerns the ability of an existing gravity sewer system to transport ground refuse. The results of the Springfield case study show very clearly that in many sewer laterals, the scour velocities required to prevent excessive deposition of the glass and ceramic component are rarely present, if indeed at all. Moreover, it remains questionable whether the generally optimistic conclusions of the Foster-Miller studies, which would appear to show few problems to occur under steady-state conditions, are at all valid for the unsteady flow conditions actually encountered in most parts of a gravity sewer system, and, in particular, in the laterals at the periphery of the system.

In order to resolve these problems, a study of hydraulic transport of ground refuse in a simulated system of sewer laterals is proposed, with the objective of extending the findings of the existing Foster-Miller studies to unsteady flow and solids load conditions. The experiments should be conducted in a test loop of eight-inch glass sewer several hundred feet long, and with a representative selection of appurtenances. The injection of ground refuse should be through simulated building connections spaced at appropriate intervals along the test loop, and discharges timed to simulate as closely as possible real conditions. The ground refuse injected should include the glass fraction, and the experiments run over at least weekly cycles in order that quantitative judgments on accumulation problems can be substantiated. Although it is recognized that such a simulation program may involve substantial effort and considerable sophistication in laboratory procedures, anything less would not yield information that will provide *conclusive* evidence on the feasibility of hydraulic transport in real systems.

Task 2: Field Survey of Refuse Generation and Water Consumption. The case study has been unable to fully answer the question of the feasibility of refuse grinding and sewer question because of certain data inadequacies. In particular, no data is available on the refuse generation, water consumption, and sewage production of single households. The use of average values for groups of households may be dangerous if the degree of correlation between these three variables is unknown. If in fact households with high refuse generation also generate high sewage quantities, the problem of adequate grinding water will be less acute than is suggested by use of average values. Unfortunately, knowledge of this correlation is crucial to a judgment of feasibility, and, therefore a field investigation to rectify this deficiency is proposed. This field survey would involve the selection of a series of representative refuse collection truck routes in the study area, and sample a series of households on this route for water consumption and refuse generation. The program might include:

> Weekly readings of water meters on the day of refuse collection. Water meters can often be read without requiring access to the interior of a dwelling unit, thus involving no inconvenience to householders.
>
> Curbside weighing of refuse containers on the day of collection prior to pick-up by the collection crews. This sampling might be conducted half an hour ahead of the collection, involving no impediment to the collection crews. Portable scales mounted on a suitable push-cart would be adequate for this purpose. By sampling only a portion of the households on each route, the sampling crew could operate at the same speed as the collection crews, thus preserving a constant difference between the two operations. A certain number of samples could be confiscated into plastic bags for subsequent composition analysis and determination of which components could not be ground by virtue of their bulk.
>
> Determination of the maximum flow depth (and hence velocity) of the sewer at each manhole along the sample routes according to the method discussed in Chapter IV.
>
> Continuous monitoring of sewage flows in a selection of residences.
>
> Statistical analysis and interpretation of all data collected.

Because of strong seasonal variations, this study should be conducted over a 52 week period. It is, however, probably unnecessary to sample all households every week; once every four weeks would be sufficient for all but a few sample households.

Only data collected at this level of detail will allow meaningful conclusions on the feasibility of refuse grinding and the development of adequate grinder specifications. Ideally, this task should run concurrently and be closely coordinated with Task 1, and be conducted in the same Springfield case study area as used by this investigation.

Task 3: Energy Balance Studies. In the 18 months that have elapsed since the start of this wet systems evaluation, national energy shortages have reached major proportions. An evaluation of any radical innovation, such as the wet systems concept, must therefore include examination of the impact of its implementation on energy consumption, but unfortunately could not be included as part of this study for reasons of time and resources. A focus on energy *consumption* is especially important in view of the energy market distortions resulting from government controls. Energy *costs*, and total systems costs, may thus not necessarily be an adequate indicator of the true social costs of the various alternatives.

(At first glance the trade-off appears to be savings in fuel for collection vehicles as opposed to increased electricity use for grinding and treatment plant operation. However, to the extent that anaerobic digestion and its methane by product could satisfy a substantial portion of treatment facility power requirements, the net impact of a wet system on energy consumption would probably be positive.)

Task 4: Evaluation of Potentially Hazardous Components in Refuse-Sewage Mixtures. Phase I of this investigation established the possibility of potential problems arising from the addition of potentially hazardous materials to the treatment plant. But because there is no actual evidence, only indirect estimates that are inconclusive, it is recommended that a series of laboratory investigations provide some facts on this question. Advanced instrumentation analyses of simulated treatment plant inflows and secondary effluents should provide the necessary evidence of higher (or lower) concentrations of specific materials (pesticides, herbicides, toxic heavy metals) resulting from the addition of ground refuse. Such evidence would further allow appropriate additional advanced waste treatment processes (or changes needed to already existing processes to be identified with some degree of confidence and thus make estimates of treatment cost in the presence of ground refuse more credible than those that can presently be made.

Task 5: Development of Alternative Grinding Concepts. The results of our investigations show clearly that existing grinding concepts envisaged for wet systems are unlikely to be implemented for economic reasons. Replumbing of existing housing as would be necessary under the Foster-Miller concept is prohibitively expensive and must be regarded as infeasible. On the other hand, grinding at high consistencies, as called for by the Nebiker-Meier concept, requires a pressurized building connection, the cost of which is also very high. Moreover, the question of how much grinding water is available, and what minimum solids concentrations are necessary to prevent deleterious effects in the sewer system under the unsteady flow conditions encountered in practice, are obviously crucial to the development of grinder specifications. Consequently, additional effort in this area rests on the results of Tasks 1 and 2.

Since the major cost of existing grinding concepts lies not in the grinder itself, but in ancillary arrangements, a successful grinding concept that would avoid these would have some chance of success in removing a major barrier to a wet systems implementation. One such alternative concept might involve grinding at high consistency, but discharging to the building connections only at such times when the flow from other domestic appurtenances, such as following toilet flushing or washing machine discharge, would provide adequate dilution water.

Task 5 should be divided into 3 phases. In Phase I, alternative concepts should be evaluated with the help of laboratory simulations that would examine the behavior of refuse slurries and their dilution and mixing with other domestic wastewaters. Phase II would develop an appropriate design which should be constructed and tested in a third phase. Any demonstration project would obviously depend on the availability of an already constructed and tested grinder.

Task 6: Comprehensive Re-evaluation of the Concept. Completion of the previously specified Tasks 1 through 5, and the study shortly to be conducted by the EPA National Environmental Research Center in Cincinnati that will obtain further data on the quality parameters and conventional treatability of ground refuse-sewage mixtures, should allow an evaluation of the concept that is founded on much more concrete evidence than has been available to this study. This proposed re-evaluation would be in a position to make a definitive judgment on the economic and technical feasibility of the concept, and, if found to be feasible, would have as a major goal the planning of a subsequent demonstration project. This re-evaluation is felt to be very necessary prior to commencement of a demonstration program that would involve investments of a very much higher order of magnitude than the studies previously conducted.

APPENDIX A: SEWER SURVEY DATA

BLOOMFIELD STREET

Time Period	Max. Depth of Flow (in.)	d/D	According to the Design Manual (Figure 18)				According to Foster Miller Data (Figure 19)					
							0%		.5%*		1.0%*	
			Q/Q_f	V/V_f	Q cfs	V max. ft/sec	V/V_{fo}	V max. ft/sec	V/V_{fo}	V max. ft/sec	V/V_{fo}	V max. ft/sec
14-15 Aug 73	2 1/2	.14	.03	.4	.207	1.52	.49	1.86	.37	1.40	.25	.95
15-16 Aug 73	1	.06	-	.21	-	.80	.29	1.10	.18	.68	.11	.42
16-17 Aug 73		Storm water from side drains washed away depth marks										
17-18 Aug 73	2 1/2	.14	.03	.4	.207	1.52	.49	1.86	.37	1.40	.25	.95
18-19 Aug 73	2 1/2	.14	.03	.4	.207	1.52	.49	1.86	.37	1.40	.25	.95
19-20 Aug 73	2	.11	.015	.33	.1035	1.254	.40	1.52	.29	1.10	.20	.76

REMARKS: Invert of pipe always appeared to be clean.

MAINTENANCE RECORD: No Blockages.

*The actual velocity of flow with refuse will be slightly higher since the depth of flow with refuse is slightly higher than the depth of flow without refuse (see text).

DENVER STREET

Time Period	Max. Depth of Flow (in.)	d/D	According to the Design Manual (Figure 18)				According to Foster Miller Data (Figure 19)					
							0%		.5%*		1.0%*	
			Q/Q_f	V/V_f	Q cfs	V max. ft/sec	V/V_{fo}	V max. ft/sec	V/V_{fo}	V max. ft/sec	V/V_{fo}	V max. ft/sec
14-15 Aug 73	No reading possible due to the unavailability of a ladder to reach the bottom of the manhole											
15-16 Aug 73	1	.1	.015	.3	.0165	.615	.40	0.82	.29	0.59	.20	0.41
16-17 Aug 73	1 1/4	.125	.025	.37	.0275	.758	.48	0.98	.36	0.74	.25	0.51
17-18 Aug 73	2	.2	.06	.47	.066	.96	.58	1.19	.49	1.00	.37	0.76
18-19 Aug 73	2 1/4	.225	.08	.50	.088	1.03	.62	1.27	.54	1.11	.41	0.84
19-20 Aug 73	2 1/8	.212	.07	.49	.077	1.00	.60	1.23	.51	1.04	.39	0.80

REMARKS: 4" sludge cake on bench of manhole.

MAINTENANCE RECORD: No Blockages.

*The actual velocity of flow with refuse will be slightly higher since the depth of flow with refuse is slightly higher than the depth of flow without refuse (see text).

ALDREW TERRACE

Time Period	Max. Depth of Flow (in.)	d/D	According to the Design Manual (Figure 18)				According to Foster Miller Data (Figure 19)					
							0%		.5%*		1.0%*	
			Q/Q_f	V/V_f	Q cfs	V max. ft/sec	V/V_{fo}	V max. ft/sec	V/V_{fo}	V max. ft/sec	V/V_{fo}	V max. ft/sec
14-15 Aug 73	2 5/8	.26	.11	.55	.165	1.485	.65	1.76	.58	1.57	.46	1.24
15-16 Aug 73	3	.3	.14	.6	.210	1.620	.69	1.86	.65	1.76	.54	1.46
16-17 Aug 73	2 1/2	.25	.10	.54	.150	1.458	.64	1.73	.57	1.54	.45	1.22
17-18 Aug 73	2 1/2	.25	.10	.54	.150	1.458	.64	1.73	.57	1.54	.45	1.22
18-19 Aug 73	2	.2	.06	.47	.090	1.270	.58	1.57	.49	1.32	.37	1.00
19-20 Aug 73	2 1/2	.25	.10	.54	.150	1.458	.64	1.73	.57	1.54	.45	1.22

REMARKS: Bone deposits on invert of pipe - removed by 20 Aug 73.

MAINTENANCE RECORD: No Blockages.

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*The actual velocity of flow with refuse will be slightly higher since the depth of flow with refuse is slightly higher than the depth of flow without refuse (see text).

MALDEN STREET

Time Period	Max. Depth of Flow (in.)	d/D	According to the Design Manual (Figure 18)				According to Foster Miller Data (Figure 19)					
							0%		.5%*		1.0%*	
			Q/Q_f	V/V_f	Q cfs	V max. ft/sec	V/V_{fo}	V max. ft/sec	V/V_{fo}	V max. ft/sec	V/V_{fo}	V max. ft/sec
14-15 Aug 73	2 1/2	.21	.06	.49	.144	1.47	.60	1.80	.50	1.50	.37	1.11
15-16 Aug 73	2 1/4	.19	.05	.47	.120	1.41	.58	1.74	.47	1.41	.35	1.05
16-17 Aug 73	2 1/8	.18	.05	.45	.120	1.35	.57	1.71	.45	1.35	.33	0.99
17-18 Aug 73	2 1/2	.21	.06	.49	.144	1.47	.60	1.80	.50	1.50	.37	1.11
18-19 Aug 73	2	.17	.04	.42	.096	1.26	.56	1.68	.43	1.29	.31	0.98
19-20 Aug 73	1 3/4	.146	.03	.40	.072	1.20	.50	1.50	.37	1.11	.26	0.78

REMARKS: Invert of pipe always appeared to be clean.

MAINTENANCE RECORD: Rooted for roots in: 1950, 1955, 1958, 1959, 1961, 1962.
Rooted for Blockage in: 1958, 1967, 1972.

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*The actual velocity of flow with refuse will be slightly higher since the depth of flow with refuse is slightly higher than the depth of flow without refuse (see text).

FENWAY DRIVE

			According to the Design Manual (Figure 18)				According to Foster Miller Data (Figure 19)					
							0%		.5%*		1.0%*	
Time Period	Max. Depth of Flow (in.)	d/D	Q/Q_f	V/V_f	Q cfs	V max. ft/sec	V/V_{fo}	V max. ft/sec	V/V_{fo}	V max. ft/sec	V/V_{fo}	V max. ft/sec
14-15 Aug 73	2	.2	.06	.47	.084	1.175	.58	1.45	.49	1.23	.37	0.93
15-16 Aug 73	1 1/2	.15	.03	.40	.042	1.000	.51	1.28	.39	0.98	.29	0.73
16-17 Aug 73	1 1/4	.125	.025	.37	.035	.925	.48	1.20	.36	0.90	.25	0.63
17-18 Aug 73	1 3/4	.175	.05	.44	.070	1.100	.55	1.38	.43	1.08	.33	0.83
18-19 Aug 73	2	.2	.06	.47	.084	1.175	.58	1.45	.49	1.23	.37	0.93
19-20 Aug 73	1 1/2	.15	.03	.40	.040	1.000	.51	1.28	.39	0.98	.29	0.73

REMARKS: Sewer always appeared to be clean.

MAINTENANCE RECORD: 1960 Blockage due to paper napkins.

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*The actual velocity of flow with refuse will be slightly higher since the depth of flow with refuse is slightly higher than the depth of flow without refuse (see text).

WHITE OAK ROAD

			According to the Design Manual (Figure 18)				According to Foster Miller Data (Figure 19)					
							0%		.5%*		1.0%*	
Time Period	Max. Depth of Flow (in.)	d/D	Q/Q_f	V/V_f	Q cfs	V max. ft/sec	V/V_{fo}	V max. ft/sec	V/V_{fo}	V max. ft/sec	V/V_{fo}	V max. ft/sec
14-15 Aug 73	1 1/2	.15	.03	.40	.033	.800	.51	1.02	.39	0.78	.29	0.58
15-16 Aug 73	1 1/2	.15	.03	.40	.033	.800	.51	1.02	.39	0.78	.29	0.58
16-17 Aug 73	1 1/4	.125	.025	.37	.027	.740	.48	0.96	.36	0:72	.25	0.50
17-18 Aug 73	1 3/4	.175	.050	.44	.055	.880	.55	1.10	.43	0.86	.33	0.66
18-19 Aug 73	3	.30	.14	.6	.154	1.200	.69	1.38	.65	1.30	.54	1.08
19-20 Aug 73	1 3/8	.138	.027	.38	.030	.760	.49	0.98	.37	0.74	.26	0.52

REMARKS: Sand and grease deposits visible on side of pipe.

MAINTENANCE RECORD: No Blockages.

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*The actual velocity of flow with refuse will be slightly higher since the depth of flow with refuse is slightly higher than the depth of flow without refuse (see text).

ACREBROOK ROAD

	Max. Depth of Flow		According to the Design Manual (Figure 18)				According to Foster Miller Data (Figure 19)					
							0%		.5%*		1.0%*	
Time Period	(in.)	d/D	Q/Q_f	V/V_f	Q cfs	V max. ft/sec	V/V_{fo}	V max. ft/sec	V/V_{fo}	V max. ft/sec	V/V_{fo}	V max. ft/sec
7 Aug 73	3	.3	.14	.6	.154	1.20	.69	1.38	.65	1.30	.54	1.08
15-16 Aug 73	3 1/2	.35	.2	.67	.22	1.34	.72	1.44	.73	1.46	.62	1.24
16-17 Aug 73	2 1/2	.25	.1	.54	.11	1.08	.64	1.28	.57	1.14	.45	0.90
17-18 Aug 73	3 1/8	.313	.17	.62	.187	1.24	.70	1.40	.67	1.34	.56	1.12
18-19 Aug 73	3	.3	.14	.6	.154	1.20	.69	1.38	.65	1.30	.54	1.08
19-20 Aug 73	3	.3	.14	.6	.154	1.20	.69	1.38	.65	1.30	.54	1.08

REMARKS: 1.5 inch layer of grit and garbage grindings on invert.

MAINTENANCE RECORD: No Blockages

*The actual velocity of flow with refuse will be slightly higher since the depth of flow with refuse is slightly higher than the depth of flow without refuse (see text).

APPENDIX B: LIST OF ABBREVIATIONS

A & R	Division of Ashes and Refuse (presently Division of Solid Waste
BOD	Biochemical Oxygen Demand
Btu	British Thermal Unit
cm	Centimeter
cfs	Cubic Feet Per Second
COD	Chemical Oxygen Demand
cu ft	Cubic Feet
cu ft/Mg	Cubic Feet Per Million Gallons
cu yd	Cubic Yard
dB	Decibels
dBA	Decibels Weighted on the A-Sound Level Scale
DPW	Department of Public Works
DSW	Department of Solid Waste
fps	Feet Per Second
gal/cap/day	Gallons Per Capita Per Day
ha	Hectares
Hg	Mercury
HH	Household
Kg	Kilograms
Kw	Kilowatt
Kkg	Metric Tons
Kwh	Kilowatt-Hour
ℓ	Litres
lb/cap/day	Pounds Per Capita Per Day
LNG	Liquified Natural Gas
Mg	Million Gallons
Mgd	Million Gallons Per Day
mg	Milligrams
mg/ℓ	Milligrams Per Liter
μg/ℓ	Micrograms Per Liter
m	Metres
mm	Millimeters
m/sec	Metres Per Second
MW	Megawatt
N	Nitrogen
P	Phosphorus
ppb	Parts Per Billion
ppm	Parts Per Million
psi	Pounds Per Square Inch
SMSA	Standard Metropolitan Statistical Area
sq mi	Square Miles
SS	Suspended Solids
SWM	Solid Waste Management
TKN	Total Kjehdahl Nitrogen
VS	Volatile Solids
yr	Year